INDIA—THE LAND AND PEOPLE

MINERALS OF INDIA

Mrs. MEHER D. N. WADIA

Edited by

Dr. D. N. WADIA F.R.S.

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FOREWORD

THIS IS another addition to the Series that the National Book Trust has planned on "India—the Land and People".

The origin of the Series is the result of a discussion that I had with the late Prime Minister, Pandit Jawaharlal Nehru. When I first put the idea before him, he not only heartily approved it but gave many suggestions for making it more complete and attractive. It was his opinion that such a Series of books on India will form a permanent library of knowledge on every aspect of this country and is sure to make constructive contribution for national advancement in knowledge and education.

The Series proposes to cover every aspect of the country and will deal with its geography, geology, botany, zoology, agriculture, anthropology, culture, language, etc. Its ultimate aim is to create a kind of comprehensive library of books on India. We have endeavoured to have the books written by acknowledged authorities on various subjects and in a scientific way. Every effort is being made to see that they are easily understandable by the ordinary educated reader. The factual knowledge regarding the various subjects concerning India would be available to any ordinary reader who is not a specialist and who would like to have a knowledge of the subject in a relatively simple language.

We have been fortunate in getting the guidance of leading experts and scientists in various fields for this Project. In fact without their active cooperation it would not have been possible to plan the Series. We are thankful to our Board of Honorary Editors who are eminent specialists and leaders in their field for helping us in producing these volumes for the benefit of the ordinary reader.

One of the objects of the Series is to make it available in as many Indian languages as practically possible. The work of translating them in various languages will be taken up as soon as the original books are ready. In fact a few volumes might be originally written in some of the languages.

We have received full support from the Ministry of Education of the Government of India and the State Governments. They are lending their help in many ways not the least by permitting scientists working under them to write for the Series. I would like to take this opportunity of thanking them. Without their help it would not have been possible to undertake this enterprise of national utility.

I am very grateful to my colleague, Professor M. S. Thacker, Member of the Planning Commission, for agreeing to be Co-Chief Editor. His enthusiastic collaboration has greatly helped in planning the Series successfully.

NEW DELHI B. V. KESKAR
May 12, 1966

PREFACE

MINERALS AND metals form the life-blood of the world's present-day industrial civilization. India has lately awakened to this, her annual mineral production, which at the turn of the Century was worth less than Rupees 100 million has, since the Second World War, been stepped up to over Rupees 2,200 million today. The importance of planning and development of industries based on minerals and metals as capable of bringing in ample dividends is now being realised. The National Book Trust of India's publication of the present Manual is, therefore, quite timely as it will help the intelligentsia of the country to take a healthy interest in India's mines and minerals, a subject until lately beyond the purview of the average citizen.

The present book is not a text-book of minerals, or a catalogue of the industrially utilisable fabricated mineral products of India. But it has been compiled with the object of bringing to the general public broad knowledge of the economic mineral substances found in the rocks of India, their occurrences and availability, mining and production, uses and their place in the national economy, for the present and the future. The compiler, Mrs. Meher D. N. Wadia, has constantly kept this objective in view as an educationist, and has planned the text accordingly. Her coordinated treatment of the subject material *vis-a-vis* India's industrial planning will, I am sure, prove interesting and informative to the general reader.

NEW DELHI
October, 1965

D. N. WADIA

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CHAPTER 1

ROCK SYSTEMS OF INDIA—AN OUTLINE OF THE GEOLOGICAL FORMATIONS

All minerals and mineral products are derived from rocks forming the crust of the Earth. In this chapter, therefore, a sketch of the geological periods and their main rock-formations is given. The accompanying table gives the sequences in chronological order of the various rock systems of India formed in the successive geological ages.

Geologically India is divided into three component units: (1) the triangular peninsular land-mass of the Deccan; (2) the high chain of the Himalayas and the related mountains bordering the Peninsula to the west, north and east; and (3) the great plains of India lying between these two units—the Indo-Gangetic Plains, stretching from Punjab to Assam. The divergent physical features of these three segments are clearly related to their geological history and structure. The Peninsula of India is one of the oldest and most stable blocks of the earth; the Himalayas are amongst the youngest mountain-systems of the world and the Indo-Gangetic plains are yet of subsequent growth. The accompanying table gives the sequences.

Archaean System

The rocks belonging to this system are the most ancient rocks forming the earth's crust—they are the gneisses, schists and granites along with extremely metamorphosed[1] sedimentary rocks, which lie at the base of rock-systems belonging to all the subsequent geological ages.

The Archaean rocks of India cover a large area of the Deccan and parts of Bihar, Madhya Pradesh, Orissa and Rajputana as well

[1] Metamorphism is the sum total of changes which rocks undergo when subjected to sub-terranean heat and pressure.

GEOLOGICAL FORMATIONS OF INDIA

Era	Geological Systems (Standard)	Age in million years	HIMALAYAS	PENINSULA
QUARTERNARY	Recent		Recent river deposits. Loess,	Newer alluvia. Desert
	Pleistocene	1	Indo-Gangetic alluvium. Glacial deposits.	deposits. Older alluvia. Laterite
TERTIARY	Pliocene	10	Upper Siwalik	Cuddalore sandstones
	Miocene	29	Tertiaries of the Outer Himalayas. Lower Siwalik	Assam & Coastal deposits
	Eocene	70	Subathu beds. Nummulitic limestones.	Deccan Trap
SECONDARY	Cretaceous	139	Cretaceous of Kashmir & Spiti	Trichinopoly & Assam Cretaceous. Bagh beds, Lameta beds.
	Jurassic	185	Jurassic of Kashmir & Spiti (Tal series)	Upper Gondwana, Jurassic of Cutch
	Triassic	235	Triassic of Kashmir & Spiti (Krol series)	Panchet & Mahadev series.
PRIMARY	Permian	246	Products beds, Zewan series	Lower Gondwana
	Carboniferous	280	Carboniferous of Spiti & Kashmir	—
	Devonian	320	Muth series of Spiti & Kashmir	—
	Silurian	360	Silurian syst. of Spiti & Kashmir	—
	Cambrian	500	Haimanta syst. of Spiti & Kashmir	—
ARCHAEAN	Algonkian		Dogra, Simla Slate, Daling series	Cuddapah & Vindhyan Systems
	Archaeozoic	3500	Salkhala, Jutogh series Gneisses & Schists	Aravalli systems Dharwar systems Gneisses

as some parts of the central ranges of the high Himalayas, Gilgit Ladakh, Garhwal, Nepal and Assam. They belong to two phases—igneous, gneisses and schists (Archaean system proper) and the highly metamorphosed primitive sediments which have been metamorphosed into gneisses and schists, quartzites, marbles, etc. (Dharwar system). The Dharwar system is economically of great importance, as it contains many of the principal ore-deposits and industrially useful minerals.

Cuddapah System

After a long interval of time during which the archaean rocks were uplifted into mountain-chains and other features resulting from earth movements, followed by an era of erosion and sedimentation, this system of rocks was laid down on the old denuded surface of the Peninsula. This is known as the Cuddapah system. They consist of slates, quartzites and limestones with jaspers. They have undergone far less folding and metamorphism than the strata of the Archaean system and are hence only partly metamorphosed. These rocks are wholly unfossiliferous, though it is probable that primitive life had originated on the Planet in this age. Rocks of this system are found in the Cuddapah district of Andhra and the Chhatisgarh area of Madhya Pradesh. They form a prominent band of highly compressed rocks in the Aravallis from Delhi to Ajmer (Delhi system) and are also developed in the Godavari valley, Bijawar and Gwalior. The aggregate thickness of the Cuddapah system is over 20,000 ft. Undoubted representatives of the Cuddapah system are not recognised in the Himalayas but it is probable that the basal part of the Dogra, Attock and Simla slates is of Cuddapah affinities.

Except for building stones and asbestos veins, the Cuddapah system is devoid of minerals of commercial utility.

Vindhyan System

Rocks of this system rest upon the denuded surface of the Cuddapahs. Typical development of this system is in the Vindhya mountains and their outcrop stretches from Aravallis to the Son

valley today. The rocks are divisible into lower Vindhyan and upper Vindhyan, separated by an unconformity. Though they are eminently fitted for preservation of fossils, the rocks, which are wholly of marine origin, are completely barren of any organic remains, though it is probable that both animal and vegetable life was in existence on earth during this age. Few representatives of Vindhyan system occur in the Peninsula south of Narmada, except in patches at Kurnool, Guntur and Bijapur districts. The most important mineral occurrence in the Vindhyans is the diamond; pebbles containing both the gem and the industrial variety are found in some conglomerate beds in the upper Vindhyans. The next important product of this system is an unlimited stock of excellent building stones suitable for public and monumental buildings—sandstones, limestones and slates, as well as materials for lime and cement.

PALAEOZOIC (CAMBRIAN TO LOWER CARBONIFEROUS SYSTEMS)

After the emergence of the Vindhyan strata from the sea, the Peninsula of India, the whole of the Deccan south of latitude 28° remained a stable land-area without experiencing any geological disturbance, such as submergence underneath the sea, folding and mountain-building, etc., for a period of several hundred million years. Rocks of the upper Vindhyan system have therefore retained their original horizontal bedding.

For the geological record of the succeeding post-Vindhyan ages, we have to go to the extra-Peninsular regions—the Salt Range of Punjab, Kashmir, Spiti area of North Kangra district, and Nepal, where representatives of marine formations belonging to the Cambrian, Ordovician, Silurian, Devonian and lower Carboniferous are preserved in detached outcrops; these systems are fossiliferous and their geological age is easily determinable by their contained fossils correlating them to the world's standard Palaeozoic systems.

A continuous sequence of strata, generally containing typical fossils (Trilobites, Brachiopods, Corals, etc.), commencing from the Cambrian up to the Lower Carboniferous, has been met with in

Spiti (northern part of Kangra), and in the Lidar Valley and Hunduwara district of Kashmir. A parallel group representative of these ages is also met with in the Simla, Garhwal, Kumaon and Assam Himalayas, though the rocks there do not contain fossils and their correlation is uncertain.

The extra-Peninsular part of India, together with the adjoining tracts of Burma, Tibet and Hazara remained submerged under the sea in isolated basins for the greater part of the Palaeozoic.

Gondwana System

With the beginning of Upper Carboniferous, a series of earth-movements encompassing the whole Earth took place and affected the course of geological history differently in the extra-Peninsular and the Deccan regions. In the north, a wide continuous sea (the Tethys) extended from the western Mediterranean to China and remained a prominent feature of the Mesozoic geography of the Earth till end of the Cretaceous. In the south, a large Continent encompassing Africa, India and Australia, emerged as a result of the earth movements. This southern Continent which is known in Geology as Gondwanaland, also included parts of South America and Antarctica.

A series of terrestrial and fluviatile deposits laid down on the surface of this vast continent in a chain of faulted basins constitute the geological records of this part of the world from Upper Carboniferous to the Cretaceous period. Contemporaneously with these Gondwana land-deposits of the south, there were being laid down in the northern sea bordering the extra-Peninsula marine fossilliferous deposits. Hence, a dual facies[1] of geological formations from the Permian to the Cretaceous exists in India—a terrestrial facies containing remains of fossil plants and land-inhabiting animals in the Deccan and a marine facies containing fossil ammonites and molluscs in the Himalayas, during the geological periods Permian, Triassic, Jurassic and Cretaceous.

[1] "Dual facies" indicates two different aspects of the same rock formation at different locations.

Gondwana System (Upper Carboniferous—Lower Cretaceous)

This system of formations started with a Glacial age (Talchir) during which the area of India from Rajputana to the Godavari Valley was covered under glacial ice. This was succeeded by a great thickness of sandstones and shales enclosing seams of coal, containing fossil plants indicating a succession of fossil floras. The Coal Age of India (Damuda) is coeval with the Permian of Europe. The next series, overlying the Damuda, are the Panchet and Mahadev series of Central India, barren of coal, but containing remains of labyrinthodonts and reptiles, besides plant remains. The succeeding Gondwana stages are the Maleri and Kota, carrying the bones and skeletons of dinosaurs and other reptiles as well as fish remains. The top beds of upper Gondwana system are met with at Jabalpur and in Cutch, containing fossils belonging to the higher plant life of the period, *viz.*, conifers, succeeding the ferns which pre-dominated in the lower Gondwanas.

Economically the Lr Gondwana system of rocks is of the highest importance in India, as its strata enclose valuable deposits of coal. The coal-fields of Bengal, Bihar, Madhya Pradesh and other provinces contain a reserve of over 50,000 million tons of good and average-grade coal, besides iron-ore and fire-clay.

Upper Carboniferous and Permian of the Himalayas

These rocks are found mostly developed in Kashmir and Spiti and form the base of a thick pile of marine *fossiliferous* strata belonging to the Mesozoic periods up to the end of the Cretaceous, deposited on the floor of the Tethys sea on the north of Gondwanaland. In Kashmir, there is a thick series of volcanic lavas (Panjal Traps) associated with the characteristic Productus-bearing limestones. In the rest of the Himalayas in the Simla, Garhwal, Nepal, Middle Himalayas, these systems are widely developed, but are totally unfossiliferous.

Triassic System

Triassic rocks, mostly fossiliferous limestones, containing a rich ammonite fauna are found in intermittent patches in the

middle and northern ranges of the Himalayas forming the Tibetan zone, from Hazara and Kashmir to Assam. Their fossils enable a close correlation of the Himalayan Trias with Trias of the Alps and the rest of Europe. The Trias of Kumaon, Garhwal and Nepal, designated as the Krol system, is unfossiliferous.

Jurassic System

These rocks overlie the Trias and form a conspicuous horizon, especially in the Tibetan zone of the Himalayas. They show a full development in the Spiti area, but not in Kashmir. Marine Jurassic strata are found in Jaisalmer and Bikaner in Rajasthan containing suits of ammonite fossils. They are also developed in great force in Kutch. Some plant-bearing Gondwana beds associated with marine strata have been observed as coastal deposits on the Madras coast of Gondwanaland, which by this time had begun to disintegrate as an Indo-African Continent.

Cretaceous System

A large variety of rock-formations belonging to this age are met with in India. On the mid-Deccan plateau, a vast pile of volcanic ash-beds and lava-flows, aggregating 6,000 feet in vertical thickness and covering 200,000 sq. miles from Bombay to Nagpur, was formed in the upper Cretaceous time (Deccan Trap). Cretaceous fluviatile deposits form the top of Upper Gondwana beds in some parts of the Peninsula. On the Madras coast between Pondicherry and Tiruchirapalli, there is met with a well-developed upper Cretaceous system of strata, carrying a varied assemblage of Cretaceous sea-life resting on the ancient Archaean rocks. They also occur in small patches in the Narmada valley, north Gujarat and Assam.

At the end of the Cretaceous, the vast Mesozoic Continent of Gondwanaland finally broke up and its constituent units either foundered down to give rise to sea-basins, according to one hypothesis, or they drifted away to form separate distant land-masses, according to another. In the Himalayan area, the Cretaceous age is well represented by marine fossiliferous beds in Hazara, Kashmir

and along the Tibetan zone of Kashmir, Nepal and Assam. The end of the Cretaceous period in the Himalayas is marked by a shallowing of the sea after the long series of deposits laid down on its floor since the beginning of the Permian. The floor of the Tethys began to rise after the end of the Cretaceous, as is indicated by a few isolated deposits of Nummulitic limestones left by the retreating waters.

There are few mineral deposits of economic value in the Cretaceous rocks, except in the Deccan lavas, which furnish building stones of some value and the laterite and bauxite deposits capping them, produced as a result of sub-aereal denudation. The well-known agates of Cambay are also derived from the Deccan Traps.

Eocene System

This is the dawn of the Tertiary era of earth-history. During it was defined the present geographical outline of the Indian Peninsula, after it was separated from Gondwanaland. The commencement of the uplift of the Himalayan chain from the floor of the Tethys sea was another significant event. Typical Eocene rocks are met with in Jammu and Simla sub-Himalayas and also in Assam and the Upper Indus basin in Ladakh. They are fitfully developed to the north of the Himalayas on the Tibetan plateau. The characteristic formation of this age is the foraminiferal Nummulitic limestone.

In the Peninsula, the Eocene system is of restricted occurrence. It overlies the Deccan Trap in Cutch and Cambay and continues southwards in a strip along the Gujarat coast and underneath the shallow Cambay Gulf. In Assam, these rocks cover a large area. The Assam and Gujarat Eocene support the productive oilfields of India. Scattered outcrops of the Eocene are found in Rajputana and along the Malabar and Coromondal coasts.

Besides petroleum, the chief mineral deposit associated with the Eocene rocks in India is coal (lignite).

Oligocene and Miocene

A thick series of estuarine and fluviatile deposits fringing the

outer Himalayas of Jammu, Kangra and Simla are products of this age. A great Boundary fault separates them from the older formations of the Middle and Lesser Himalayas. The second prominent uplift of the Himalayas took place during the Miocene. In Assam, the rocks of this age overlie the Eocene at two localities, but in the rest of the Peninsula, the Miocene is poorly developed in Kutch, Kathiawar and at Karikal, except at Cuddalore, on the Coromondal coast, where it is well formed and encloses a thick series of lignitic coal-beds of much industrial value to south India.

Siwalik System (Middle Miocene-Pleistocene)

The estuarine and fluviatile deposits, mentioned above as being laid down along the foot of the rising mountains, continued to grow all through the period of Middle Miocene to lower Pleistocene, from the abundant sediments supplied by the numerous streams draining the mountains to the north. This system of sandstones, clays and shales attained a thickness of over 20,000 feet and entombed in its strata are bones and skeletons of a varied assemblage of mammals, from primitive elephants to anthropoid apes, some of them on the line of human ancestry. The Siwaliks form the outermost foothills of the Himalayas along their entire length from Punjab to Assam.

In the Peninsula, rocks of Siwalik age occur in the Perim island and at Quilon and at Karikal.

Pleistocene and Recent

A great refrigeration of climate took place in the northern hemisphere culminating in a Glacial Age, during which much of Europe and North America were covered under ice-sheets. In India, the glacial conditions prevailed only in the Himalayas where evidences of existence of four Glacial and Inter-Glacial ages are well recorded in the moraines left by the glaciers and the *Karewa* deposits of the Kashmir Valley.

The Indo-Gangetic Plains

Thick alluvial deposits filled up the great depression, separating the Himalayas from the Peninsula, which came into being as a

concomitant of the Himalayan uplift. This depression, believed to be between 15000—20000 ft. deep, went on deepening *pari passu* with the deposition of thousands of feet of sand, silt and clays brought down by the rivers of the Indus-Ganga system. The resulting Indo-Gangetic plains now occupy an area of nearly 300,000 square miles from Rajputana to Assam.

Among the other geological formations of this period are the laterite cap of the Deccan—a product of sub-aereal alteration of surface rocks of the Deccan region; raised beaches along the coasts and other coastal deposits; sand-dunes, etc.; the Cave-deposits of Kurnool and Billa Surgon and, more important, the desert sands covering large areas of Rajputana and Cutch.

The soils capping the surface rocks of India, either alluvial or residual, humanly speaking the most important geological formation, are largely a product of Pleistocene and Recent Age.

Early Man is believed to have appeared in India in about the Middle Pleistocene period, approximately 500,000 years ago.

CHAPTER II

MAN, MINERALS AND METALS

THE VARIOUS mineral products of the rock systems of India outlined in Chapter I, are the ores and minerals, which man has used in his development throughout the ages. Almost every stage of human civilisation has been marked by a corresponding development of the medium of expression whether it be the creation of an image or the construction of shelter or an implement of daily use. From the crudest flint implement of 5,00,000 years ago to the latest precision tools and the world-orbiting artificial satellites, man has all along made bold and large-scale experiments in the use of minerals which have, in their turn, shaped the destiny of man. It has been so mainly in the realm of: (*a*) agriculture and production of food, (*b*) clothing, (*c*) shelter, (*d*) commerce and industry and (*e*) transport and communication.

As one looks around, the tractor farming, the wide range of heavy machinery for mines, mills and factories, mineral fertilizers as well as the munitions—all these bear ample testimony to the indispensability of minerals in the life of Man. The ever-changing techniques of construction engineering, the raw materials for road, rail and air transport, etc., demand an ever-increasing use of metals and minerals. The cultural life of human beings would have remained stagnant, if there were no metals in the service of the printing press, means of communication, musical instruments and other forms of social cultural expression and entertainment.

This being the role of minerals in modern existence, they should form a valuable asset in the natural resources of any country. Economic minerals are classified into strategic minerals, critical minerals, key minerals and the remaining common minerals. These, however, should not be considered as rigid groups of minerals since the distinction is gradually disappearing with the growing complexity and inter-dependence of their uses. For practical purposes, every nation looks at its mineral resources from

the viewpoint of su... ...icie... ...nd deficiencies. These again are relative concepts ... ...di... ... the demand of a developing economy. For ins... specialised industries absorb minerals like mica, kyanite ... e and rare metals, *e.g.*, germanium, zirconium, cerium, etc ...everal metallic, ferrous and non-ferrous natural products, *e.g.*, iron, manganese, chromium, aluminium comprise the second group of minerals which supply the needs of commerce, transport and everyday needs of an organised community. A third group has entered the field comparatively recently—the group of atomic minerals—which in combination with a range of metallurgical products, alloys and accessories is employed for generation of Power and production of lethal weapons and munitions of war. To explore the sources of mineral wealth and place them in the service of man should form an essential part of national reconstruction programme of every progressive nation.

An appraisal of the total min... esources of India so far known to geologists brings home t... ...act that the mineral wealth of India is not inconsiderable for a c...untry of her size and population and that it encompasses a sufficient range of useful products that are necessary to make a modern civilised country more or less industrially self-contained. Except in the case of minerals such as iron-ore, aluminium-ore, titanium-ore, mica and a few other minerals, the resources in economic minerals and metals are, however, limited. Chances of discovery of new mineral deposits of any extent and richness by ordinary geological methods are not many, though the recent geophysical methods of locating underground mineral occurrences by electrical, magnetic, gravimetric and seismic methods seem to offer possibilities of bringing to light hitherto undiscovered but, in some cases, suspected deposits of petroleum, coal-measures, natural gas, underground water, metallic lodes, etc.

Nature has made a very unequal territorial distribution of minerals in the Indian region. The vast alluvial plains tract of Northern India is devoid of mines of economic minerals. The Archaean terrain of Bihar and Orissa, possesses the largest con-

centration of ore depos such as iron, manganese, copper, thorium, uranium, aluminium, chromium; industrial minerals like mica, sillimanite, phosphates; and over three-fourths of India's reserves of coal including coking coal. The iron-ore reserves lying in one or two districts of Bihar and in the adjoining territories of Orissa are calculated at over 8,000 million tons, surpassing in richness and extent those of any known region. There are large reserves of manganese-ores; over 50 percent of the world's best mica—block, splittings and sheet—is supplied by the mica mines of Kodarma and Gaya in Bihar. The second minerally rich State is Madhya Pradesh, carrying good reserves of iron and manganese ores, coal, limestone and bauxite. Madras has workable deposits of iron, manganese, magnesite, mica, limestone and lignite. Mysore State has yielded all the gold of India, besides producing appreciable quantities of iron, porcelain clays and chrome-ores. Hyderabad has good reserves of secondgrade coal, besides being a potential source of several indu minerals. Kerala possesses enormous concentrations of heavy mine sands of high strategic importance calculated to contain, together with lesser deposits along the Malabar coast, some 200 million tons of ilmenite, besides monazite, zircon, rutile and garnet in workable quantities. The States of Uttar Pradesh and (Eastern) Punjab have been far less productive and have scarcely as yet figured in India's statistics. Rajasthan, for a long time absent in India's mineral returns, is gradually be- ; a productive centre, holding promise for the future in non- metals (copper, lead and zinc), uranium, mica, steatite, and precious stones (aquamarine and emerald). Gujar Assam supply about 3½ million tons of much needed petroleum and its products. Assam also bears important reserves of Tertiary coal. West Bengal's mineral resources are confined to coal (annual mineral capacity about 16 million tons) and iron-ore. Of the vast ent of the Himalayan region, the only proved mineralised region of importance is the territory of Kashmir south of the Great Himalayan Axis, with its coal (some of it anthracitic), aluminium-ore, sapphires and some minor industrial minerals. But for the large magnesite reserves and the partly-known copper

deposits of Kumaon and Sikkim and some fairly wide-spread bodies of iron-ore in these areas, the rest of the Himalayan region is a veritable *terra incognita* as regards economic minerals. The same is applicable to Sikkim and Bhutan region. Nepal can be considered a fairly mineralised terrain where occurrences of cobalt, nickel and copper-ores are reported, but which has not yet been fully explored geologically.

The rock-systems of India possess in varying degrees most of the minerals and metals. The various useful products they yield, their detailed occurrences, and some facts regarding the production of the most important ones are dealt with in the following Chapters.

The following table gives the quantity and value of the annual production of the leading economic and industrial minerals of India during recent years:

Mineral	*Quantity*		*Value (Rupees)*
Asbestos	2,700	tons	2,55,000
Barytes	40,800	,,	8,70,000
Bauxite	620,700	,,	60,26,000
Beryl	1,100	,,	7,42,000
Building Stones	—		14,00,00,000
Chromite	100,770	,,	60,40,000
Clays (Industrial)	720,000	,,	95,00,000
Coal	66,000,000	,,	158,70,00,000
Copper	8,000	,,	2,87,25,000
Corundum	600	,,	2,65,000
Diamonds	2,200	carats	5,60,000
Glass-sand	216,000	tons	23,62,000
Gold	5,000	kgs	5,62,00,000
Graphite	1,500	tons	1,50,000
Gypsum	1,050,000	,,	73,60,000
Ilmenite	214,000	,,	1,10,50,000
Iron-ore	14,700,000	,,	12,10,00,000
Pig-iron	2,000,000	,,	4,00,00,000
Steel	4,500,000	,,	100,00,00,000

Mineral	*Quantity*		*Value (Rupees)*
Kyanite & Sillimanite	58,000	,,	1,17,50,000
Lead-concentrate	5,500	,,	20,10,000
Limestone	23,000,000	,,	10,84,00,000
Magnesite	262,000	,,	46,25,000
Manganese-ore	1,300,000	,,	9,00,00,000
Mica	7,200	,,	2,50,00,000
Ochre	75,000	,,	8,50,000
Petroleum	3,000,000	,,	23,00,00,000
Salt	10,550,000	,,	24,80,00,000
Saltpetre	3,000	,,	16,50,000
Steatite	100,000	,,	42,00,000
Zinc-concentrate	10,000	,,	28,00,000

CHAPTER III

WATER

Wells, Springs, Artesian Wells

Besides its use for domestic and agricultural purposes, water has many important uses in manufacturing and engineering operations; the geologist is often called upon to face problems regarding its resources and supply. Porous water-bearing strata exist everywhere among the old sedimentary formations as well as among recent alluvial deposits, but a knowledge of the geological structure is necessary in order to tap these sources with the maximum of efficiency. A large part of the rain that falls in India is speedily returned to the sea, only a very small percentage being allowed to soak underneath the ground. This arises from the peculiar monsoonic conditions of the climate which crowd into a few months all the rainfall of the year, which rapidly courses down in flooded streams and rivers. The small percentage which is retained soaks down and, flowing in the direction of the dip of the more pervious strata, saturates them upto a certain level (*level of saturation*) and, after a variable amount of circulation underground, issues out again on a suitable outlet being found in the form of springs, wells or seepages. In India, the great alluvial plains of the Indus-Ganga are a great reservoir of such stored-up water, and yield large quantities of sweet water by boring to suitable depths below the surface. Wells, the most common source of water in India, are merely holes in the surface below the line of saturation, reaching the more porous rock-beds, in which water accumulates by simple drainage or by percolation. Springs are common in the rocky districts where pervious and impervious strata are inter-bedded, inclined or folded, or where a set of rocks is traversed by joints, fissures or faults. If a porous water-bearing stratum with a wide outcrop is enclosed between impervious strata above and below it, and bent into a trough, conditions arise for artesian wells when a boring is made reaching the water-bearing stratum. Such ideal conditions,

however, are rarely realised actually, but there are some other ways by which less perfect artesian action is possible. The formation of an under-ground water-tight reservoir, either by the embedding of tongues of gravel and sand under impervious alluvial clays, the abutting of inclined porous strata against impervious, unfissured rocks by means of faults,[1] or the intersecting of large fissures in crystalline rocks, gives rise to conditions by which water is held underground under a sufficient hydrostatic pressure to enable it to flow out when an artificial boring is made reaching the water. Artesian wells are not of common occurrence in India, nor are conditions requisite for the formation of artesian areas of any magnitude often met with. Artesian wells are possible in the alluvial districts of North India and in Gujarat, by the embedding of pockets of loose gravel or coarse sand in the ordinary clayey alluvium.

Tube-wells from 400-1000 feet deep, are a simpler means by which supplies of underground water of good quality can be tapped in the alluvial districts for domestic, industrial and agricultural use. Thousands of tube-wells have been bored since 1947, many of which have a discharge capable of irrigating 400 acres of agricultural land. Tube-wells of 6 to 8 inch diameter yield as much as 60,000 gallons per hour. Wells of this calibre are, however, few and their discharge depends more on the water-bearing capacity of the sub-stratum tapped than on the diameter of the tube. Tube-well water, being derived from depth, is bacteriologically purer and freer from organic impurities than ordinary well or surface waters, though there may be a greater proportion of chemically dissolved salts in it.

In the drier parts of the country, surface-running water is harnessed by engineers for irrigation and power development. India has made great advances since 1860 in irrigation and hydraulics and made striking progress in the last few years in investigating a number of engineering schemes for river training, water conservation, flood protection, irrigation reservoirs and electric power generation.

[1] Upward, downward, oblique or side-ways movement of rock masses along a line of breakage caused by earth movements.

THERMAL AND MINERAL SPRINGS—These occur in many parts of India, especially in mountainous districts like North Punjab, Bihar, Assam, Himalayan foot-hills, Kashmir, etc. Among them are the sulphurous (which are the most common), saline, chalybeate, magnesian and other springs according to the principal mineral content of the waters. There are over 300 such thermal and mineral springs known in India. Thermal sulphurous springs are very numerous on the outcrop of the Eocene limestone rocks of Punjab and Uttar Pradesh. Some thermal springs have a temperature exceeding 150° F. But high temperature springs are rare in India. Chalybeate springs are common in the foot-hills of the Himalayas. Several springs of radioactive water are also known. A number of thermal springs from Ratnagiri to Gujarat are suggestive of the course of the Malabar Coast fault-line.

Springs of the following localities may be noted:

Assam: Of the two important hot-water springs, one is at Garampani about 27 miles east of Jowai and the other is near the Nambar river falls near Golaghat in Sibasagar district. Both these have clear and potable water; but the Nambar spring has a distinct sulphurous smell due to hydrogen sulphide gas.

Bihar: A number of well-known radioactive and non-radioactive springs are located in the Rajghir hills in Patna district and parts of Hazaribagh, Monghyr and Santhal Paraganas districts and in some of the coalfields.

Gujarat: Mineral springs are found at Kawa in Bharuch district, Lasundara in Khera district, Tuwa near Godra in Panchmahals and at Anaval in the Surat district. The Tuwa spring is highly radioactive and carries radon gas derived from radium.

Madhya Pradesh: Hot springs are reported to occur at Anboni in Chhindwara district, Anboni and Samoni in Hoshangabad district and at Tatapani in Sarguja district.

Maharashtra: Numerous mineral springs with radioactive properties are situated along the coast between the sea and the Western Ghats. The southernmost of these occur near Pali Sapa Son and Kadalni in Kolaba district; near Konkar, Satiwali, Vajrabai and Vajreshwari in Thana district and near Ked, Unhara,

Aravali, Tural Rajwadi, Sangameshwar and Rajapur in Ratnagiri district.

Therapeutic and medicinal virtues are ascribed to mineral springs in Europe. The claim of some springs in India to possess curative properties for skin complaints, goitre, arthrites, muscular and other bodily disorders needs investigation and has to be scientifically proved and their therapeutic value established. There is scope for developing health centres and tourists resorts round some of these springs.

CHAPTER IV

CLAYS

THE ROLE of clay in our daily life hardly needs introduction. It is the kind of earth which is easy to approach and, when moistened, possesses a high degree of plasticity and tenacity. Throughout human history it has been the premier material (or the foremost of Nature's resources, next only to water) coming under man's hand for moulding. Early man's progress in living has been judged by his mastery over clay and his ingenuity in fashioning it. Hence ancient pottery has been the yard-stick of archaeological studies. From the date ascribed to the most ancient archaeological find to the modern days of electrical insulators, clay has been used in diverse forms with correspondingly diverse processes of its refinement. Starting as a basic raw material for building and utensils, it has reached a constantly widening industrial application in the manufacture of bricks, tiles, earthen-ware pipes, sanitary ware, ceramics, porcelain, as filler material in the manufacture of rubber, linolium, imitation leathers, paper products,insecticides, as whitening and sizing material in textiles, as drilling mud, as fire-clay in metallurgy and, to a lesser extent, in the manufacture of medicines and cosmetics. All these show the wide range of manufactures requiring a variety of clays and their ever-increasing demand.

CLAY AS BUILDING MATERIAL

Besides tiles and bricks, clay has, for centuries, been the basic building and cementing material in human dwellings. Wherever alluvial clay caps the earth, baked clay-bricks are a handy medium of house construction and brick-manufacture a flourishing industry. The Indo-Gangetic alluvium covering thousands of square miles is an inexhaustible source of clays, for tiles and brick-making. Mangalore and the surrounding areas are the home of flourishing industry of ceiling, roofing and paving tiles. Argillaceous strata

of this clay, used in making porcelain and sanitary ware occur over a large area in the Ranigunj coalfield and other alluvial tracts of West Bengal.

China Clay (Kaolin)

Pure China clay or Kaolin has resulted from the decomposition of the felspar of the gneisses and occurs plentifully in the Archaean system of rocks in the earth's structure. While, generally speaking, China clay deposits of workable size are widely distributed in the country and occur in useful aggregates in Bihar, Delhi, Jabalpur, Kerala, Madras, Deccan, Mysore, Orissa, Rajasthan, Saurashtra and West Bengal, the following records of its distribution may be noted:

Andhra Pradesh: The mica belt near Gudur shows Kaolin deposits as well as other types of clays with scope for development of ceramic industry.

Assam: Kaolin is recorded from various parts of Garo, Khasi and Jaintia hills; below the Cherra sandstone deposits; Dora river in Lakhimpur; Mikir hills; Nambor river and Barapathar in Sibsagar district. The last two yet need detailed investigation.

Bihar: Bihar contains large reserves of high-grade China clay. Important deposits occur near Chaibasa in Singhbhum; south of Ray Barkakana of the Eastern Railway in Ranchi district; near Mangal Hat in Santhal Paraganas and Patharghatta in Bhagalpur district. Small deposits occur in parts of Monghyr and Ranchi districts.

Gujarat: A large deposit of China clay occurs near Eklara and Techawa along the banks of the Sabarmati river separating the districts of Mehsana and Sabarkantha. The clays are of excellent quality and are comparable in many important respects to the best variety of imported clay. The estimated reserves are of the order of 2.5 million tons. Pockets of China clay occur along the right bank of Mahi river, 3 miles north of Savalia Railway Station in Khera district. Large deposits also occur near Babia, Dungar, Kari Dhar and Jaderra Dhar in Khera district.

Himachal Pradesh: Extensive and valuable deposits are found

enclosed in the Crystalline rocks of Bushaher of the Upper-Mahasu and between Arsang and Lipa.

Jammu and Kashmir: Large deposits of China clay are known from Udhampur district of Jammu occurring in 4-12 feet thick beds.

Kerala: Among the large and valuable deposits are those at Kundara in Quilon *taluk* (which has a well-established ceramic factory). Kaolin deposits also occur at Keezhupallikara, Puloot, Mulanthuruthy and Amballoor in Mukundapuram *taluk* of Trichur district, Palayangadi, Vellur, Kannapuram and Tiruchchebaram in Chirakhal *taluk* of Cannanore district and Mulinja, Uppala, Bare, Ajanur and Padukai in Kasargod *taluk* in Cannanore district. The deposits are particularly well-developed in Quilon area and are drawn upon for the local ceramic industry.

Madras: There are some good quality deposits in Sivaganga *taluk* of Ramanathapuram.

Mysore: The State's porcelain factory derives its kaolin from the mines at Arjunabettahalli and Gollahalli in Bangalore district. There are important open-cast workings in Bagespura in Hassan district. Other deposits exist near Narsimharajapura, Koppa and Thirthahalli in the Maland region as well as near Melkote and places in Mandya district.

Orissa: Workable kaolin deposits occur around in Keonjharsgarh district and at places in the Karanjia sub-division of Mayurbhanj district. The China clay from some of the latter deposits is being used by potteries and a rubber company located in the area.

Rajasthan: China clay is reported from Buchara in Jaipur district and Gehun in Jodhpur district. More important occurrences are near Mar in Bikaner district.

West Bengal: In Darjeeling district and parts of Bankura, Purulia, Birbhum and Burdwan districts, workable occurrences of Kaolin have been reported.

Material for High-Grade Porcelain

The deposits of Rajmahal hills at Colgong (Pattarghatta,

Bengal-Bihar region) are of much interest both as regards the quantity available and the purity of the material for the manufacture of superior grades of porcelain. Similar deposits, though on a restricted scale, are found in Bhagalpur and Gaya in Bihar, and in many parts of Maharashtra, Kerala, Madras, Mysore and Orissa.

Terra-Cotta

China clay of an impure variety, coloured buff or brown, is known as *terra-cotta*; it finds employment in unglazed, large-size pottery, statues, etc. and, to some extent, for architectural purposes. *Terra-Cotta* clay deposits are of more common occurrence and are more widespread than of pure kaolin in India.

Ball-clays

Also known as Potter's Clay, these are highly plastic clays of good binding power and are fairly widely distributed in the country; they are found more commonly in Assam, specially in the alluvial tracts.

Fuller's Earth

Fuller's earth is a white, greenish-grey or greenish-brown, yellow, soft and earthy material. It is used as a detergent agent and has a high absorbent power for many substances for which reason it is used for washing and cleaning purposes. It was formerly used for "fulling" or cleaning woollen fabrics and cloth because of its absorbent properties causing it to remove greasy and oily matters. In modern times it is used in refining petroleum, vegetable oils and in the preparation of cosmetics.

It is obtained by quarrying some beds of yellow and brown earthy shale belonging to the Eocene rock-system.

As regards the production of fuller's earth, the following locations are important:

Gujarat: Deposits occur near Lakhanka in Bhavnagar district and near Nandam, Ran, Mewasa, Habardi, Virpur in Jamnagar district. Extensive deposits occur in the Lakhpat, Anjar and Bhuj *taluks* of Kutch district.

Jammu and Kashmir: A seven-foot bed of fuller's earth of fairly long spread occurs in the Salkhala series of Budil, Rajouri (Jammu region) containing a large stock of the mineral.

Madhya Pradesh: It is found, among many other places, in the Lower Vindhyan rocks of Jabalpur district (Katni).

Mysore: Fuller's earth of economic importance is obtained from Korvi, Chincholi *taluk*, Gulbarga district. "Korvi Earth", as it is named there, has been in much demand by oil-filtering and cleaning industries.

Rajasthan: Fuller's earth is obtained from the Eocene rocks of Jaisalmer and Bikaner where it is quarried and sold under the name of *Multani mattee.* Its occurrences are reported from Palana, Kesasdesar and Mudh in Bikaner district, Kapurdi and Alamsaria in Barmer district and Manda and Mandai in Jaisalmer district.

Bentonite

The variety of plastic clay known as Bentonite is a soft, white, greyish or greenish clay with large absorbent powers. It is employed in discolouring oils, in water-softening and as a filler for thickening drilling muds used in the sinking of oil wells. Bentonite occurs in association with a Siwalik conglomerate near Bhimber, Jammu province. The bed is two feet thick and extends for many miles. Bentonite also occurs in the Jodhpur region in Rajasthan, near Hathisingh-ki-Dhani, Giral, Alki Bhadres, Jasanai, Thumbli and Ganga in Barmer district and near Daragama in Sawai-Madhopur district. The deposits in Barmer district have been proved to contain some 734,000 tons. Bentonites from Barmer district and of Jammu region are particularly employed for oil-drilling and for foundry purposes.

Fire-Clay

Fire-clay (or refractory clay) is a clay which is devoid of iron and salts of potassium and sodium which can, therefore, stand the heat of furnaces without fusing. They are used in the manufacture of refractory bricks needed to line high-tempera-

ture furnaces. Fire-bricks of high refractory quality and other refractories are indispensable in metallurgy, requiring rafractories which can stand upto a range of 1400°C. Workable beds of refractory clays occur as follows:

Assam: Fire-clay commonly occurs in association with the coal seams of Upper Assam, but has nowhere been worked so far. Fire-clay from near Jowai in Jaintia hills has been reported to be of good quality.

Bihar: Deposits of fire-clay occur inter-bedded with coal seams in the Gondwana coal-fields. The important deposits are those in Jharia and Ranigunj coalfields. In the Jharia coal-fields, the reserves of fire-clay are estimated to be of the order of 5.3 million tons upto a depth of 20 feet, while, in Kumardubi-Mugma area of Ranigunj coalfield, the estimated reserves are over 1.7 million tons up to the same depth. (Bands of quartz-rich schist and granulites near Rakha Copper mines and Kendadih in Singhbhum district have also been found suitable for making refractory bricks.)

Gujarat: The clay deposits of Rajpura and Belatia in Kalol *taluk* (Panchmahals) are suitable for manufacture of coloured glazed ware as well as fire-bricks. The estimated reserves are of the order of about 100,000 tons. Large quantities of fire-clay occur at Rajpur, Talavdi, Kankavati and other places in Zalawad district and in a number of localities in Anjar, Bhuj and Nakhtrama *taluks* of Kutch district.

Madras: Clays suitable or refractory bricks occur around Panruti and in the Neyveli lignite fields in South Arcot district.

Mysore: Some fire-clay deposits at Nandagudi in Hoskote *taluk* of Bangalore district and in Bangalore itself are exploited. Refractory clays also come from Karadibande in Kolar district and Thinnalu in Bangalore district.

Punjab: A deposit of clay suitable for manufacture of refractories, sanitary ware and other stone-ware occurs at Sikandarpur (28° 29′: 77° 6′).

Rajasthan: Refractory clays of limited reserves occur near Basu, Phalodi and Raesena in the Sawai-Madhopur district,

Palana and Mudh in the lignite areas of Bikaner district and Kita and Devicot in Jaisalmer district.

West-Bengal: Fire-clay seams of wide extent and of great potential, ranging from one foot to six feet in thickness, occur in Ranigunj coalfields in association with the Coal-seams. The main occurrences are found to the north and south of Khudia *nala*.

Semi-Refractory Clays

These are mostly categorised with fire-clays; they are good enough for the manufacture of bricks, tiles, sanitary ware, synthetic stone slabs, pipes and other stone-ware and are often known as stone-ware clays. Their occurrences are:

Andhra Pradesh: Semi-refractory clay is abundantly found in the district of Vishakapatnam (Araku valley), East Godavari, West Godavari, Cuddapah, Nellore, Kurnool and Adilabad. The important semi-refractory clay occurrences are being worked in East Godavari district; West Godavari district, Cuddapah district; Hyderabad district; and Adilabad district.

Gujarat: Light grey to pink plastic clays interbedded with sandstones occur near Himmatnagar, Katwar and Hapa in Sabarkantha district. The reserves of clay in these deposits are likely to be enormous. They are worked near Himmatnagar and are sent to Ahmedabad for manufacture of stoneware pipes.

Rajasthan: Industrial clays are reported from Ghaskoki-Dhani in Jaipur district, Baswa Gate in Alwar district, and Mundwa, Khajwana, Nimri, Indawar and Saradana in Nagaur district.

Lithomarge

A kind of clayey rock associated with laterite. Usually between the lateritic cap and the underlying basalt or other rocks over which it rests, there is a lithomarge-like rock or bole, a sort of transitional product, showing a gradual passage of the underlying rock (basalt or gneiss) into laterite. It has some of the properties of industrial clays.

Assam: Lithomarge occurs abundantly in association with

coal beds of Garo hills. Good exposures occur near Tura, especially north-west of Rongrengiri coalfields and in places along the southern slopes of Garo and Khasi hill ranges occurring below the Nummulitic limestone horizon. The lithomarge with low iron and alkali content appears to be suitable for use as fireclay, though it has not so far been put to this test. Some of the clays or shales of Upper Assam have been conveniently used for the preparation of "oil-well drilling mud".

West Bengal: Occurrences of various types of lithomargic clay are reported from parts of Bankura, Purulia, Birbhum and Burdwan districts.

India thus possesses enough resources of various clays for industrial uses to be able to meet all her requirement. The total production of clays in India for various industrial purposes is worth about Rs 450 lacs per annum on an average; this may be contrasted with the value of clays raised in the United States of America for various manufactures, which amounts to about Rs. 200 crores per year. In 1964 India produced a total of 780,000 tons of industrial clays, whereas its average annual production of China clay, mostly for ceramic uses, has remained roughly 180,000 tons per annum.

Though not strictly speaking a clay-rock, we might conveniently discuss laterite here as an economic product of India, derived originally from clays by disilification.

Laterite

Laterite is a kind of vesicular clayey rock, composed essentially of a mixture of the hydrated oxides of aluminium and iron with often a small percentage of other oxides, chief among which are manganese and titanium oxides. The two first-named oxides are present in variable ratios, often mutually excluding each other; hence we have numerous varieties of laterite which have bauxite at one end and an indefinite mixture of ferric hydroxides at the other. The iron oxide generally preponderates and gives to the rock its prevailing red colours; at places the iron has concentrated in colitic concretions, at other places it is completely removed,

leaving the rock bleached white or mottled. At some places again the iron is replaced by manganese oxides; in the laterite cap over the Dharwar rocks this is particularly the case. Although the rock, originally described as laterite by Buchanan, from Malabar does contain clay and considerable amounts of combined silica, in the wide terrains of what is obviously the same rock in other parts of India there is no clay (kaolin) and the silica present is colloidal and mechanically associated. According to present usage it is the latter, clay-free rock which has come to be regarded as typical laterite. According to the preponderence of any of the oxides, iron, aluminium or manganese, at the different centres, the rock constitutes a wokable ore of that metal. Usually between the lateritic cap and the underlying basalt or other rocks over which it rests, there is a lithomarge-like rock, or bole, a sort of transitional product, showing a gradual passage of the underlying rock (basalt or gneiss) into laterite.

Laterite has the peculiar property of being soft when newly quarried but becoming hard and compact on exposure to the air. On account of this property it is usually cut in form of bricks for building purposes. Also loose fragments and pebbles of the rock tend to re-cement themselves into solid masses as compact as the original rock.

Distribution of Laterite

Laterite occurs principally as a cap on the summit of the basaltic hills and plateaus of the highlands of the Deccan, Madhya Bharat and Madhya Pradesh. In its best and most typical development it occurs in the hills of the Bombay Deccan. In all these situations it is found capping the highest flows of the Deccan traps. The height at which laterite is found varies from about 2000 feet to 5000 feet and considerably higher, if the ferruginous clays and lithomarges of the Nilgiri mountains are to be considered as one of the many modifications of this rock. In thickness the lateritic cap varies from 50 to nearly 200 feet; some of these are of small lateral extent, but others are very extensive, individual beds often covering an immense surface of the country continuously. Laterite

is by no means confined to Deccan Trap area, but is found to extend to isolated outcrops from as far north as the Rajmahal hills in Bihar to the southern extremity of the Peninsula. In these localities the laterite rests over formations of various ages and of varying *lithological* composition, *e.g.*, Archaean gneiss, Dharwar schist, Gondwana clays, etc. The laterite of the above-noted areas is all of high level, *i.e.*, it never occurs on situations below about 2000 feet above sea-level. The rock characteristic of these occurrences is of massive homogeneous grain and of uniform composition. This laterite is distinguished as *high-level laterite*, to differentiate it from the *low-level laterite* that occurs on the coastal low lands on both sides of the Peninsula, east and west. On the Malabar side, its occurrences are few and isolated, but on the eastern coast the laterite occurs almost everywhere rising from beneath the alluvial tracts which fringe the coast. Low-level laterite differs from the high-level rock in being much less massive and of detrital origin, from its being formed of the products of mechanical disintegration of the high-level laterite.

CHAPTER V

SANDS, LIME, CEMENT

THE MOST predominant component of sand is quartz in well-rounded grains (felspar and hornblende grains also occur) with a fair proportion of calcareous grains. The latter are casts of *marine foraminiferal* shells[1]; they help to suggest the site of origin of the sand with which they are intimately mixed. As is characteristic of all aeolian sands, the sand grains are well and uniformly rounded, by the ceaseless attrition and sorting they have received during their inland drift. In other respects sands belonging to localities widely apart have a common composition. For instance, Rajasthan sand is indistinguishable from the sea-shore sand. Common river-sands are used for mortar-making. Recent calcareous sands, consisting mostly of shells of foraminifers, have consolidated into a kind of coarsely-bedded free-stone at some places on the coast of Saurashtra peninsula miliolite.

GLASS SAND

In India ordinary white sand is used for the manufacture of inferior variety of glass, provided it is free from minerals such as mica, black magnetite and various silicate minerals. It is more or less pure silica sand with very low iron content. Sand deposits of requisite purity suitable for glass manufacture are distributed in various localities as shown below:

Bihar: Glass-making silica is available from the friable sandstone west of Dehri-on-Sone, from sandstones near Mangal Hat in Rajmahal hills in Santhal Paraganas and from the widely distributed quartz sand in the State. Some sandstones, free from iron and magnesia, give sand pure enough for glass industry.

Gujarat: Himmatnagar, Baroda, Rajkot, Bhavnagar and Jamnagar districts have small deposits of glass sands. Sporadi-

[1] Shells of minute sea animals.

cally worked sandstones near Himmatnagar produce white to slightly pink material capable of passing through 20 mesh sieve. The bands of white sandstone near Gaztoli in Sankhed Mahal and near Padhambi in Baroda region yield high-grade sands containing 99.93 per cent SiO_2. Sandstones from Baroda and Uar yield some quantities of glass sands.

Jammu & Kashmir: The deposits of a pure white, soft granular quartzite occur in Poonch area together with masses of crumbling powdery silica resulting from metasomatic replacement of limestone.

Kerala: Considerable reserves of white sands for glass manufacture are present in Alleppey district in the neighbourhood of Shertallai, Kakkothamangalam and Pallipuram. Other occurrences are at Eroor, Puthiyakavu, Nittur and places near Ernakulam.

Madras: Suitable white sands are available near Ennore adjacent to Madras city.

Madhya Pradesh: Good quality sand suitable for glass making occurs in the river at Jabalpur.

Maharashtra: Glass sands occur near Bhatkal in North Kanara, but they are actually worked in Ratnagiri and Bijapur districts.

Mysore: A type of glass sand, popularly known as "silver sand" is a friable quartzite, occurring in parts of the Chiknayakanahalli schist belt of Mysore. Vein quartz is quarried and crushed at Sonnehalli near Kengeri for the glass works situated at Bangalore.

Orissa: Occurrences of friable sandstone are reported at Bonai in Sundergarh district and in Keonjhar district. Similar sandstone at Pavisia and Sonvi in Mayurbhanj district and at Naraj and Telgar in Cuttack district provide material for glass industry in Calcutta and at Barang near Cuttack.

Punjab: Sandstone suitable for glass manufacture occurs in a ridge south of Tahla (28° 00' : 76° 05') in Mahendergarh district. Glass sand is also available at Jaijon Doaba and from the Sutlej river bed near Gujar Nangal in Hoshiarpur district,

at Garh Shanker, Una and along the north-west flanks of the Hoshiarpur-Siwalik range and at Barhwin ridge in Kangra district.

Rajasthan: Important occurrences of glass sands are reported near Barodhia in Bundi district, Kundi in Kota district, Dhula and Dholpur in Jaipur district, Madh in Bikaner district, Dantilia and near Zawar in Udaipur district and in places in Sawai Madhopur district.

Uttar Pradesh: Glass sands are worked in Chakia in Varanasi district between Murari and Bala Behat, in Jhansi district, and specially in the neighbourhood of Shankargarh, Lohgarh and Bargarh, popularly known as Naini area, in Banda and Allahabad district. The requirements of most of the glass factories in northern India are supplied by these regions. Similar sands are reported in Robertsgunj plateau of Mirzapur district.

A recent survey of India's resources in silica sands and rocks suitable for glass industry has produced a useful summary regarding the distribution, localities, extent and purity of the important glass-sand deposits of the country. According to it, several valuable sources of glass sands are Bargarh, south of Allahabad, covering an area of 100 sq. miles where the sand is 96 to 97 percent pure SiO_2 and only 0.1 to 0.03 percent Fe_2O_3 and some parts of Rajasthan and the coast of Kerala, where large spreads of white quartz beach-sands cover over a hundred square miles of the coast. Pure quartz sand (see p. 152 for quartz) free from all iron impurities and possessing a uniform grain and texture is of better economic value in the manufacture of glass. Such sands are not common in India; but in recent years they have been obtained from the crushing of pure quartzose Vindhyan sandstone at several localities in Talegaon (Poona), Jabalpur, Ambala in Punjab, Allahabad in Uttar Pradesh, from Gondwana (Damuda) sandstone of the Rajmahal hills, in Assam State and from Cretaceous sandstones and Archaean and other pure quartzite of some parts of Madras and Maharashtra and at Barodhia (Bundi district, Rajasthan). Thick deposits of a pure, white, soft, granular quartzite in Poonch district and masses of crumbling powdery silica

resulting from metasomatic replacement of limestone near Garhi Habibullah, Hazara are other available deposits.

Quartz, thus, is the essential basic raw material for manufacture of glass. India, which till recently imported large quantities of manufactured glass every year has now an expanding glass industry by improving the grading and processing of the sand and by research into the production of special types of glass, like optical glass, scientific laboratory glass, etc. The average annual production of glass in India is 125,000 tons valued at Rs. 5,00,00,000. (Gem sands and metallic sands, *viz.*, ilmenite, magnetite and monazite are dealt with elsewhere in this book).

Cement and Mortar

Limestone (*Chuna ka pathar*), as its name suggests, is the main source of lime. Lime for mortar-making is obtained by burning limestone. Lime, when mixed with water and sand, is called mortar, which, when it loses its water and absorbs carbonic acid gas from air, "sets" or hardens. Hence its use as a binding or cementing material. In the plains of India the only available source of lime is "Kankar", which occurs plentifully as irregular concretions disseminated in the clays. The clay admixture in Kankar is often in sufficient proportion to produce, on burning, a hydraulic lime. Travertine or calc-tufa ('tufa' is a kind of calcium carbonate), sea-shells, recent coral limestones, etc. are also drawn upon for the kiln where a suitable source of these exists. When limestone containing argillaceous matter in a certain proportion is burnt, the resulting product is *cement*, in which an altogether different chemical action takes place when mixed with water. The burning of limestone ($CaCO_3$) and clay ($x\,Al_2O_3$, $y\,SiO_2$, $z\,H_2O$) together results in the formation of a new chemical compound—silicate and aluminate of lime–which is again acted upon chemically when water is added, hardening it into a dense compact mass. For cement-making, either some suitable clayey limestone is used or, more commonly, the ingredients, limestone and clay, are artificially mixed together in proper proportion (Portland cement). A high-grade, rapid-hardening cement, rich in aluminous content

(cement fondu) used in special structures, can be manufactured from aluminous laterites mixed with appropriate quantities of limestone.[1]

The Eocene system, which is rich in Nummulitic, oolitic, miliolitic and coral limestones, offers favourable conditions for cement manufacture. The occurrence of these and other older limestones in Madras, Madhya Pradesh, Rajasthan, West Punjab, Assam and other parts, in association with clays and shale are an asset to the future cement manufacture in the country. Most kinds of limestone suitable for the purpose occurring in the various geological systems of India are shown here State-wise:

Andhra Pradesh: Limestone occurs near Borra caves in Visakhapatnam district, at 12 miles east of Cherla in East Godavari district,[2] and at Bhumanlanka on the left bank of Talperu river. Taking a length of 2 miles and a width of 250 feet, the total quantity available would be about 3.4 million tons of limestones. Other workable deposits of limestone occur in Duddukuru Rajahmundry area, near Mukteswaram (269 million tons) in Krishna district, in Palnad area (Pinduguralla—17.4 million tons and Macherla area 124 million tons), Guntur, Cuddapah, Kurnool, Warangal, Karimnagar, Adilabad and Khammamett districts. The great thickness of limestones, shales and quartzites in Hyderabad and adjoining areas provides a prolific source of cement material.

Assam: The resources of high-grade limestone in this region are about the best in the country, although they occur as discontinuous bands along the southern wall of Garo, Khasi, Jaintia and Mikir hills, the quantity being practically inexhaustible. Individual bands at places vary from 20 to 700 feet in thickness. Fairly good quality limestone also occurs in the north Cachar hills and the part of Mikir hills bordering Nowgong and Sibsagar districts. Total reserves are estimated to be about 154 million tons. In Khasi hills, the Therriaghat area itself contains a reserve of about 1,000 million tons of good quality limestone.

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[1] Pig-iron is a by-product of this process.

[2] It is believed that time made from this was used for the construction of the *anicut* at Dummagudem on the Godavari river over 100 years ago.

Bihar: Limestone deposits occur in Shahabad, Hazaribagh, Ranchi, Palamau and Singhbhum districts. Those in Shahabad district are traceable for about 45 miles and extend further westwards beyond the state. The Rohtas limestones of Shahabad district are especially valuable as they are extensively drawn upon for burning as well as for building purposes. Large patches of limestone occur scattered over a zone extending from Ramgarh in Hazaribagh district to Khalari, Bhundu-Basaria, Kukuta and Religara in Hazaribagh district. Deposits at Basaria and those at Daltongunj in Palamau district and around Gola and Sondimra in Hazaribagh district are among the many new occurrences that have recently come to light. A thirty-mile belt of limestone extends from Chaibasa to Jagannathpur in Singhbhum district.

Gujarat: High-grade limestone occurs near Pasuval, Diwania Khunia and Viaramudi in Pabanpur *taluk* of Banaskantha district, near Chorwad Road Railway Station, Kunderwa, Adri Road Railway Station, Dari, Veraval Savni, Patan, Lati, Gorokhundi, Prachi, Sutrapara and Warodra in Junagarh district. Extensive deposits of good quality limestone occur near Posina, north of Idar in Sabarkantha district. Other occurrences are near Balasinor in Khera district and near Lunawada in Panchmahals. Extensive deposits of oolitic limestone are noticed near Jhura in Bhuj *taluk*, Keerai in Nakhtrana *taluk* in Kutch district. Yellow and slightly porous nummulitic limestone, noticed near Tarkeswar in Surat district is of cement grade and is estimated to contain a reserve of 2.9 million tons. Isolated small pockets of travertine occur near Chinchinagaotha, Satpuria and Dhodra in Dang district.

Miliolite limestone occurs in coastal areas around Kodinar and Okha Mandal in Jamnagar district. Fairly good quality of miliolite limestone is noticed near Piperla Sanosra, Chogal Mehtla, Naip, Gujarda, Khand and Nisaud in Bhavnagar district.

Coral limestone occurs along the coastal margins of Okha Mandal. The deposits near Mithapur alone are reported to contain about 5 million tons of coral limestone. The deposits near Gora Bhilvasi-Tejpur area are of low grade.

Himachal Pradesh: High grade limestones have been reported

from Naura, Bhangari and Jarag in Sirmur district, the quantity at Naura alone exceeding 17,000,000 tons. There are suitable occurrences also in Giri river of Sirmur district near Sataun, Bhatrog and Kyari. Reserves of these have been calculated to be of the order of 141,000,000 tons. Overlying these is the Mandhli limestone, the average composition of which is probably similar to that of natural cement rock, the reserves of which also run into many millions of tons. Limestone deposits are also reported from Khadli and Kakarhatti in Mahasu district. Remoteness of some occurrences from industrial centres and lack of communication, however, lessen their importance.

Jammu and Kashmir: Limestone suitable for manufacturing 'portland' cement is found in large quantity in Ramban, Kistwar, Doda, Ramsu, Handwara, Kaghan, Banihal, Vihi, Verang, Zamalgam-Tserkar-Doru-Nanpura belt, Achhibal and Bawan in Anantnag district, and Bandipura, Ajas, Gung-i-Sudarkut, Biru and Sonamarg-Zoji La in Sind valley. Though the Great limestone of Riasi area in Jammu district is mostly dolomitic, a thick and consistent band low in magnesia has been located recently. Clays suitable for cement-manufacture have been estimated to an extent of 29 million tons near Pampara.

Kerala: Lime-shell deposits occur near Puthur in Kasargod *taluk* of Cannanore district. The shelly layer which occurs at a depth of 3 to 12 feet from the surface has a thickness of 6 to 30 inches and is worked from February to May every year. A large deposit of lime-shell occurring in Vembanad lake, Kottayam *taluk* in Kottayam district constitutes the source for lime for the cement factories in Kerala, one of which has an annual production capacity of 50,000 tons. Limestone of fairly good quality is exposed in the coastal cliff sections in various places south of Quilon. *Kankar* limestone occurs at places in Palghat district. It is rather high in magnesia but is suitable for lime-burning. Important deposits of *Kankar* are also present in Chittur *taluk* of Palghat district near Attampathy and elsewhere. The average thickness is about 20 feet, the deposits extending over 2,500 acres.

Madhya Pradesh: Limestone occurs in the district of Jabalpur,

Rajgarh, Raipur, Bilaspur, Drug, Bastar, Sagar, Damoh, Rewa, etc. and is quarried on a large scale, particularly at Katni and Jukehi in Jabalpur district, Alaktara in Bilaspur district and near Raipur. At Katni limestone is quarried mainly for producing lime. Dolomite (dolomitic limestone, calcium magnesium carbonate) is exposed at Bhanesar, Parsoda, Khaira, Ramtola and Hardia in Bilaspur district and at Bhatapara and Patpar in Raipur district.

Madras: Limestone suitable for the manufacture of 'portland' cement occurs in Tiruchirapalli district. Other suitable crystalline limestone occurs in Salem district, in Coimbatore district, Madurai district, Tirunelveli district. The deposits in Tiruchirapalli, Coimbatore and Tirunelveli districts are under active exploitation for cement manufacture while those in Ramanathapuram are awaiting exploitation. Tufaceous (limestone), which may be used for manufacture of lime, occurs extensively in Tirunelveli, Tanjore and South Arcot districts. *Kankar* is of common occurrence in the State and is widely used by rural population for manufacturing lime.

Maharashtra: Fine-grained, grey limestone occurs at Purukepar near Alewahi Railway Station in Chanda district and near Kondara, Mardha and Niljai. Fairly good quality deposits occur at Majri and Wanjri near Rajpur Railway station in Yeotmal district. Calcareous tufa containing over 75 percent calcium carbonate occurs near Kamur, Kandur and Khandera Vadi in Ahmednagar district.

Mysore: Material for cement works in the State are drawn from Shahabad and Wadi limestone in Gulbarga district, the quarries of Bhadigund, 13 miles east of Bhadravathy and the crystalline limestone of Shimoga, Chitradurga, Tumkur and Mysore districts. Occurrences at Hosadurga and Voblapur in Chitradurga and Tumkur districts respectively are known to contain about 50 million tons of limestone averaging 3 to 4 percent of silica, 49 percent of lime and 2.8 per cent of magnesia.

Orissa: While the limestone of Sambalpur district is argillaceous, siliceous and dolomitic, limestone suitable for cement

manufacture is found near Kottametta in Koraput district and in the long belt of Lanjiberna near Rajgangpur. Limestone has been quarried around Birmitrapur since 1922. Assuming a total length of 6.4 Km. (approx. 4 miles), an average width of 225 metres (approx. 850 feet) and a depth of 30 metres (approx. 100 feet), the quantity of limestone here is estimated at 37.3 million tons. Of this 25 percent may be classed as (second grade), useful for lime-burning.

Punjab: Limestone occurs in a discontinuous belt at the fringe of the foot-hills on the north-eastern border of the State. In this belt between Tundapathar and Sheria, a reserve of 26 million tons of limestone has been estimated. The quarries at Malla (31° 46' : 77° 0') provide rich cement material. Small deposits of lime concentrates, known as calc-tufa occur near Samalgarh in Kangra district and at Biranpur, Kherakalmot and Lehra in Hoshiarpur district.

Rajasthan: Limestone suitable for manufacture of Portland cement is obtained from Ajmer, Banaswara, Bikaner, Dungarpur, Jodhpur, Kota, Tonk and Udaipur districts and in the vicinity of Sawai-Madhopur and Lakheri in Bundi district. Calcite is also reported from Maonda and Raipur in Sokar district, Paparana in Jhunjhunu district, Barna-ki-chowki and Sakhoon in Jaipur district and Rajpura in Sirohi district.

Uttar Pradesh: Besides *Kankar* which is available in abundance in various parts of the State, suitable limestone occurs in Markundi and Kotah in Mirzapur district, in the valleys of Tons, Amlawa and Jamuna rivers in the north-western portion of the State and to the south and west of Chakrata. Tufa deposits in Nainital, vicinity of Dehra Dun, and marlstone (impure limestone) in Barabanki, Lucknow, Rae Bareli and Unao districts are sources of material for lime-making.

West Bengal: Calcareous tufa containing more than 45 percent CaO, found in Darjeeling district and Western Duars area in Jalpaiguri district is a source of lime material. Local concentrations of calcium carbonate concretions developing in parts of the soil of Ranigunj coalfields in Burdwan, Bankura and other districts,

being fairly rich in lime content, provide material for lime-making.

Stone from two highly siliceous discontinuous bands of crystalline limestone along the northern flank of the hills near Ichatu and Jhabar near Jhalda and places in Purulia district is used for manufacture of low-grade lime.

Large deposits of dolomite, covering an area of 5 sq. miles, containing 19.50 to 21 percent magnesia and about 30 percent lime, reported in Buxa Duars area of Jalpaiguri district, are a possible source of raw material for lime-making.

In India, over 23 million tons of limestone of the value of approximately 110 million rupees is consumed annually. In 1963, India produced 21 million tons of portland cement.

CHAPTER VI

BUILDING STONES

IN ORDER to be suitable as building stone, a rock should have specific qualities such as capacity to stand the ravages of time and weather, requisite strength to bear strain and superincumbent weight and attractive colour and general appearance. Its structure must also be such as to allow quarrying into good-sized blocks or planes. It should possess inherent features such as joints and (in sedimentary rocks) bedding planes. It should also be capable of receiving dressing—ordinary or ornamental—without disproportionate cost of labour. Susceptibility to weather is an important factor; costly experiments have been made to judge the merits of rocks in this respect. For instance, the architects of New Delhi, who required an extensive range of rock material for a variety of purposes, building as well as ornamental, invited the opinion of the Geological Survey of India regarding the suitability of the various stones quarried in the neighbouring areas of Rajasthan and Madhya Pradesh. An officer of the Survey was specially deputed to advise on the matter after an examination of various quarries working in these States. The Dharwar system (which carries the principal ore deposits of the country) is rich in its resources of building material, *e.g.*, granites, marble, limestones, sandstones, other ornamental building stones and roofing slates. The famous marbles which are used in the best specimens of ancient Indian architecture are a product of this rock system. The Vindhyan system, while not possessing any metalliferous deposits, is rich in resources of building materials, which furnishes an unlimited measure of excellent and durable free-stones, flagstones, ornamental stones, besides the already described large quantities of limestones for the manufacture of lime and cement. The formation known as 'the Bhandar stage' has yielded materials for the

[1] An enumeration of even the chief and the more prized varieties of these would form a long catalogue.

building of some of the finest specimens of Indian architecture. The famous *stupas* of Sanchi and Sarnath, the Moghul palaces and mosques of Delhi and Agra and most of the modern Government edifices of New Delhi are built of Vindhyan sandstones. These resources are, however, scarcely used to their full extent. For instance, in northern India, the ready accessibility of brick-making materials in unlimited quantity has rendered sub-ordinate the use of stone in private and public buildings. Excellent material, however, exists, and in quantities sufficient for any demand, in many rock-systems of the country.

GRANITE

Granite, or what passes by that name, is coarsely foliated gneiss. Of its three varieties, *viz.*, biotite-granite, hornblende-granite and tourmaline-granite, biotite-granite is most widely prevalent and forms a very suitable building stone for durability and decoration. These rocks, by reason of their massive nature and homogeneous grain, are eminently adapted for monumental and architectural work as well as for massive masonries. Their wide range in appearance and colour—white, pink, red, grey, black, etc.—renders the stones highly ornamental and effective for a variety of decorative uses. The Charnockites of Madras, the Arcot gneiss, Bangalore gneiss, the porphyries of Seringapatam and many other varieties of granite obtained from the various districts of the Peninsula are attractive examples. Its durability is such that the numerous ancient temples and monuments of South India built of granite stand today almost intact after centuries of wear and, to all appearances, are yet good for centuries to come. From their wide prevalence, forming nearly three-fourths of the surface of the Peninsula, the Archaean gneisses form an inexhaustible source of good material for building and ornamental uses.[1] The following occurrences of granites are noteworthy.

Andhra Pradesh: Used in Nagarjunasagar dam and, much

[1] At Bombay, a series of tests on Indian granites was undertaken. These have proved that the granites from South Indian quarries are equal to or better

earlier, in the construction of Bombay Harbour and several public buildings, the Hyderabad granite takes the pride of place. The other rocks-those suitable for constructional purposes are the Charnockites (used in constructing Krishna barrage) and Khondalites occurring in the Circars.

Assam: Granites and granite-gneisses are found throughout the Shillong plateau. Coarse granite around Mylliem and also from a few places along the northern scarp of the plateau facing—Goalpara, Kamrup and Nowgong plains is being quarried for building stones.

Madras: Of the building stones with which the State is richly endowed, granite, gneisses and charnockites are the most widely distributed, particularly in North Arcot, Chingleput, Madurai, Western Ramanathapuram, Tirunelveli and parts of Tiruchirapalli and Nilgiri districts.

Mysore: Building stones are obtained from the surface exposures of granite-gneiss and many other gneisses many of which are remarkably fresh. These gneissic rocks have supplied building material to most of the beautiful structures in Bangalore city.

Orissa: The State has a wide distribution of granitic gneisses and khondalites of which the sculptures of the Sun temple of Konarak (Konarka) is a classic example, the figures having been carved on mottled khondalitic rocks.

Rajasthan and West Bengal: They also have, among other stones, a fair amount of jointed granite rocks.

Limestones

Limestones occur in many formations some of which are entirely composed of them. Not all of them, however, are fit for building purposes, though many of them are burnt for lime (see Chapter V). In the Cuddapah, Bijawar, Khondalite and

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than Aberdeen, Cornish or Norwegian granites in respect of compressive strength, resistance to abrasion, absorbtion of water and freedom from voids. The verdict of the various experts consulted was altogether favourable to the use of Indian granites for the purposes for which imported granite alone had been considered suitable. (*Indian Granites*, Bombay Port Trust Papers, 1905)

Aravalli groups, limestones attain considerable development, some of them being of great beauty and strength. They have been largely drawn upon in the construction of many of the noted monuments of the past in all parts of the country. Vindhyan limestones are extensively quarried in Rajasthan and form a source of building-stone as valued as that of lime and cement mentioned earlier. The Gondwanas spread over a large part of Bihar and Madhya Pradesh are barren of calcareous rocks, but the small exposures of the Bagh and Tiruchirapalli Cretaceous include excellent limestones, sometimes even of an ornamental description. The same is the case with limestones of Lower Vindhyan formation which are also extensively drawn upon for building as well as for burning purposes. The great thickness of limestone together with shales and quartzites, constituting the *Palnad series* of Hyderabad and adjoining areas, shows local variations in the rock-types, but in the main conforms to the argillaceous and calcareous nature of the system. Some of the limestones show a concretionary structure, the concentric layers exhibiting and giving to the polished rock a marble-like appearance. At some places on the coast of Saurashtra, a kind of coastal deposit occurs, known as *Porbunder Stone* (sometimes also as miliolite). It is composed of calcareous wind-blown sand, the sand grains being largely made of the casts of foraminifera, the whole compacted into a kind of white or cream-coloured, rudely bedded free-stone. The rock known as Junagarh limestone is a typical aeolian limestone situated 50 Km. inland from the sea coast and 60 metres thick. It is mainly composed of fragments of calcareous shells (most of them living species) cemented by lime. About 6 to 12 percent of foreign particles of Girnar igneous rock enter into the composition.[1] From their softness and the ease with which they receive dressing and ornamental treatment, these limestones are a favourite material for architectural purposes in Maharashtra State. Crystalline limestone, marble-like in appearance is reported to occur at San-

[1] It is believed that the Peninsula of Saurashtra stood 50 feet lower than its present level and was probably in Pleistocene time an island or a group of islands.

dara in the Sankhada Mahal, near Ther, Mithibor, Kendol, Chetapur, Malu and Bhilpur in Chhota Udepur *taluk* in Baroda district and between Hansi and Shir in Bharuch district. Limestones from Shahabad, Wadi and places in Gulbarga district of Mysore State are widely used. They take good polish and make suitable medium for flagstones, roofstones and building material in general.

The Nummulitic limestones of the extra-peninsular district, *viz.*, Hazara, Punjab and Assam are an enormous repository of pure limestone and when accessible are in large demand for building as well as for burning and road-making purposes.

MARBLES

Marble deposits of India are fairly widespread and of large extent. The principal source of the marbles is the crystalline formation of Rajasthan—the Aravalli series. Marble quarries are worked at Makrana (Jodhpur), Kharwa (Ajmer) Maundla and Bhainslana (Jainpur), Dadikar (Alwar) and some other places from which marbles of many varieties of colour and grain, including the chaste, white variety of which the Taj Mahal is built, are obtained. It was the accessibility of this store of material of unsurpassed beauty which, no doubt, gave a stimulus to the Moghul taste for architecture in the seventeenth century.

A saccharoidal dolomitic[1] marble occurs in a large outcrop near Jabalpur, where it is traversed by the Narmada gorge.[2] The famous quarries of Makrana supply white, grey and pink marbles. A handsome pink marble comes from Narmada in Kishengarh district. Jaisalmer in Rajasthan supplies a yellow shelly marble, while a fresh-green and mottled marble of exquisite finish is obtained from Motipura from an exposure of the Aravalli rocks in Baroda district in Gujarat State. A mottled rose or pink marble is found in the same locality and in one or two places in the Aravalli series in Rajasthan and in Narsingpur district of Madhya Pradesh,

[1] Dolomite is magnesian lime-stone.

[2] The well-known marble rocks occur about 18 Km. (11 miles) from Jabalpur.

whereas white mottled hard marble from near Khirasra Sejridla in Gujarat State is of ornamental value. The Kharwa quarries of Ajmer produce green and yellow coloured marbles. Black or dark-coloured marbles come from Makrana and from Kishengarh district, though their occurrence is on a more limited scale than the light-coloured varieties. A dense, black marble capable of taking an exquisite polish, largely employed in the ancient buildings of Delhi, Agra and Kashmir, with highly ornamental effect, is furnished by some quarries in Jaipur region. Coarse-grained marbles are more suitable for architectural and monumental uses; it is the coarseness of the grain which is the cause of its great durability against meteoric weathering. The fine-grained, purest white marbles are reserved for statuary use for which no other variety can serve. In the Tiruchirapalli region, the shell-limestone has compacted into a hard, fine-grained translucent stone which is much prized as an ornamental stone and used in constructions under the name of 'Trichinapoly' marble.

Black and white marbles were, at one time, worked in Mandi and Datla hills of Narnail *Tehsil* in Mahendergarh district of Punjab. It is regrettable, however, that the above-noted deposits of Indian marble do not find any market so as to encourage their systematic quarrying. The indigenous demand is not considerable nor are there any facilities for their export. The deposits, therefore, will have to wait the demand of a more thriving and more aesthetic population of the future.[1]

SANDSTONES

The Vindhyan system of rocks, though not possessing any metalliferous deposits, is as rich a repository of sandstone as of limestone indicated earlier. It furnishes unlimited, durable and attractive building material such as freestones, flag-stones, ornamental stones (besides large quantities of limestones for manufacture of lime and cement). The 'Bhander stage' has yielded materials

[1] A fine collection of Indian marbles, representing the principal varieties, is seen in the Indian Museum, Calcutta.

for building some of the finest specimens of Indian architecture. The famous *stupas* of Sanchi and Sarnath, the Moghul palaces and mosques of Delhi and Agra and the modern Government buildings in New Delhi are built of Vindhyan sandstones. The most preeminent among these are the white, cream, buff and pink Upper Vindhyan Sandstone, which have been put to an almost inconceivable number of uses. From the crude stone knives and scrapers of the Palaeolithic man to the railway telegraph boards and the exquisitely carved monoliths of its present-day successor, these sandstones have suplied for man's service an infinity of uses. It is the most widely quarried stone in India. Being both a freestone and a flagstone, it can yield, depending on the portion selected, both gigantic blocks for pillars and thin slate-like slabs for paving and roofing. The superb edifices, modern and medieval in Delhi, Agra and Rajasthan are built of red and white Vindhyan sandstone quarried from a number of sites in the vicinity. Some of the Vindhyan sandstones are so homogeneous and soft that they are capable of receiving a most elaborate carving and filigree work. Centuries of exposure to the weather have tested their durability.[1]

The Vindhyan sandstones, uniformly fine-grained in their variegated shades are sometimes mottled or speckled owing to the variable dissemination of the colouring matter or to its removal by deoxidation. The Kaimur and Bhander sandstones (of deep red tint passing now and then into softer elegant shades) make easy quarrying. No other rock formation of India possesses such an assemblage of characters rendering it so eminently suitable for building or architectural application. When thinly stratified, the rock yields flags or slabs; when the bedding is coarse the rock yields large blocks and columns.

The Sandstone obtained in Saurashtra (Jurassic outcrop at its North-East) is a light coloured freestone, largely quarried at

[1] "The difficulty in writing of the uses to which these rocks have been put is not in finding examples, but in selecting from the numerous ancient and modern buildings which crowd the cities of Uttar Pradesh and the Ganges valley generally and in which the stone-cutter's art is seen in the highest perfection." Vol. LIII, *Economic Geology* by Dr. V. Ball, 1881.

Dhrangadhra for supplying various parts of Gujarat with a much needed building material.

Newer Sandstones

To a lesser extent the Gondwana formations afford sandstones suited for building works. The Upper Gondwana has contributed a great store of building-stone to Orissa and Chanda regions. The famous temple of Puri and other richly ornamented buildings of these districts are constructed of Upper Gondwana sandstones. The fine-grained sandstone of Cuttack, Athgarh, Tirupati are much used for structural purposes. The Mesozoic (Umia) sandstone of Dhrangadhra and the Cretaceous sandstone underlying the 'Bagh beds' of Gujarat (*i.e.*, Songir sandstone) furnish Gujarat with a handsome and durable medium for its building construction.

Among the Tertiary sandstones only a few possess the quality requisite in a building-stone, whereas the younger Siwalik sandstone are all too unconsolidated and incoherent to be a medium of construction.

Laterite

Laterite is the product of a peculiar sub-aerial alteration of surface rocks under the alternately dry and humid (*i.e.*, monsoonic) weather of India. Laterite is a kind of vesicular, clayey rock, composed essentially of mixture of the hydrated oxides of aluminium and iron with often a small percentage of other oxides chief among which are manganese and titanium oxides.

Laterite is largely used as a building-stone, as it is a widespread Pleistocene surface formation of considerable extent and thickness. It has the peculiar property of being soft when newly quarried but becoming hard and compact when exposed to the air. On account of this property, it is usually cut in the form of bricks for building purposes. Loosened fragments and pebbles of thick rock tend to re-cement themselves into solid masses as compact as the original rock.

Distribution of Laterite: Laterite occurs principally as a cap on the summit of the basaltic hills and plateaus of the highlands

of the Deccan, Rajasthan and Madhya Pradesh. In its best and most typical development it occurs on the hills of the Bombay Deccan. In all these situations it is found capping the highest flows of the Deccan Traps. Laterite is by no means confined to the Deccan Trap area, but is found to extend in isolated outcrops from as far north as the Rajmahal hills in Bihar to the southern extremity of the Peninsula[1] and in Cachar district, in the basal part of the Jaintia series in Garo, Khasi and Jaintia hills in Assam.

Uses: In several parts of southern India laterite is quarried for use as a building-stone since it can be easily cut into bricks,[2] but it is not capable of receiving dressing for any architectural or ornamental use. Moreover, its wide distribution from Assam to Comorin makes laterite a widely used material for road-metal.

Slates

This is one of the units forming the bulk of the Dharwar system of rocks. Besides its use as the familiar writing slate, switch-boards and table tops, when split suitably, it is used as material for roofing, paving and shelves. The true cleavage-slate, which is the roofing and paving variety of slate, is not of common occurrence in India except in some mountain areas, *e.g.*, at Chamba and Mandi in Simla and Kangra hills in outer Himalayas and Pir Panjal in the middle Himalayas, where they make good roofing material obtainable locally for hill towns and villages.

Extensive slate beds occur in Cumbum-Markapur area in Kurnool district where slate-making is a cottage industry. Slate occurs in Cuddapah area inter-bedded with iron and manganese ores. Large deposits occur in Dhauladhar range at Kanyara, near Dharamsala in Kangra district and the vicinity of Rewari in Gurgaon district, in the Aravallis and in Kharagpur hills in Monghyr

[1] It extends to Ceylon where it forms a thick cap covering the gneiss and the Khondalite. In these localities, the laterite rests on formations of various ages and of varying lithological compositions, *e.g.*, Archaean gneiss, Dharwar schists, Gondwana clays, etc. Laterite is of fairly wide occurrence also in parts of Burma.

[2] The term 'laterite' has been derived from the latin word 'later' meaning a brick.

district in Bihar. About 60 per cent of the Indian slate production comes from Punjab. When the cleavage in slate is finely developed and regular, enabling the rock to be split into thin even plates, roofing slates are available; when the cleavage is not fine slate is used for paving. What generally are called slates are either phyllites or compacted shales in which the planes of splitting are not cleavage-planes.

Basalts of the Deccan

Known as Deccan trap, a sub-aerial, volcanic product, prevailing over a wide region of western India are used mostly by the Railways and Public Works Departments for building bridges, permanent ways, etc. The traps furnish easily workable and durable stone of great strength, but its dull, subdued colour does not recommend it to popular favour.

Trachytic and Other Acidic Lavas

Of light buff and cream colours occurring at Malad near Bombay which have, of late years, found favour in the building of public edifices.

Sylhet Traps

Found in Khasi, Jaintia and Mikir hills especially in the Koilajan area, Jamuna, Hariajan and Deopahi river-beds and near the Nambor falls, the Abor hills in N.E.F.A., useful not only in road-making but as aggregate in concrete mixtures. Along with these may be noted the Khasi greenstones occurring in the southern part of Shillong plateau.

Basement Gneiss

The oldest of gneisses are quarried extensively in parts of Rajasthan for use as building stone at present and which has been the medium of construction of temples of West India.

The present-day annual average value of building-stone out put in India is calculated at 140 million rupees.

CHAPTER VII

COAL, LIGNITE, PEAT

THE PRINCIPAL consumers of coal in India are the railways, the steel factories and foundaries, thermal power-generating units and textile and other mills and factories. To feed these and other expanding industries the coal deposits of the country are fairly extensive, most of it borne by the Gondwana rock-system, one of the two main coal-bearing rock-systems, the other being the Tertiaries.

The Gondwana coal is a laminated, bituminous coal within which dull (durain) and bright (vitrain) layers alternate. Anthracite, *i.e.*, the coal in which the percentage of carbon is more than 80, and from which volatile compounds are eliminated, is not found in the Gondwana fields. The volatile compounds and ash are, as a rule, present in too large a proportion to allow the carbon percentage to rise above 55 to 60, generally much less than that. The percentage of ash is usually high, 13 to 20, rising to as much as 25 to 30 per cent. Gondwana coal is free from moisture, but it contains sulphur and phosphorus in variable quantities. In general, Gondwana coal is good steam or gas coal. Occurrence of coking coal is limited and confined to the Jharia, Giridih and parts of Karanpura fields.

It is probable that some extent of coal-bearing Gondwana rocks lie hidden underneath the great pile of lava of the Deccan trap. At several places, chiefly in the Satpuras, denudation has exposed coal-bearing Gondwana strata, from which it is reasonable to infer that considerable quantities of this valuable fuel are buried under the formation in this and more westerly parts of the country.

The Damuda series (*i.e.*, Lower Gondwana) possesses the most valuable and best-worked coal-fields of the country.

The Tertiary rock-system bears coals of younger age which is extracted from the extra-Peninsula. Assam coal is of a high grade as fuel, while that of Jammu and Arcot (Madras) has a lower

percentage of fixed carbon. In the former it rises to as much as 53 per cent; in the latter it never goes beyond 40 per cent. The latter coal, properly speaking a lignite (brown coal), is more bituminous, friable, pyritous and contains more moisture. The last two qualities make it liable to disintegration on exposure and even to spontaneous combustion. All Tertiary coal generally has a high sulphur percentage.

With regard to its geological aspect the extra-Peninsular coal is mostly Lower Tertiary. In Assam three horizons occur—one near the bottom and one at top of the Jaintia series (corresponding to a part of the Kirthar), and a much more important one in the Barail series, somewhat above the Eocene-Oligocene boundary.

RESERVES OF GOOD COAL

Giridih and Jaintia fields	60	million tons
Raniganj, Jharia, Bokaro and Karanpura	5600+	,, ,,
Son valley fields	70+	,, ,,
Talchir field	698+	,, ,,
Satpura fields	450+	,, ,,
Ballarpur Singareni fields	45+	,, ,,
Total	7500	,, ,,

RESERVES OF COKING COAL

Giridih field	20	million tons
Raniganj field	250+	,, ,,
Jharia field	900+	,, ,,
Bokaro and Ramgarh	1315+	,, ,,
Karanpura field Korba and Singrauli	not estimated	
Total	3500	million tons

Reserves of bituminous non-coking coal of 2nd and 3rd grade are of much higher order. Experiments have shown that it is

possible to upgrade some of this coal by washing and blending. To the above-noted reserves of good-quality coal must be added the resources in Tertiary brown coal and lignite, which form a valuable addition to the mineral assets of such outlying States as Assam, Madras and Rajasthan. Assam Tertiary coal is of high quality and recent estimates of reserves contained in the coal-fields of Upper Assam and of the Garo and Khasi fields are over 2,000 million tons; the lately discovered lignite deposits at Cuddalore (South Arcot district, Madras) are calculated at a like figure, while the Rajasthan and Kutch deposits are not yet fully known. Mining operations required for the extraction of coal from these rocks are comparatively simple and easy because of the immunity of Gondwana rocks from all folding and plication. Moreover, on account of the less common association of highly explosive gases (marsh-gas or "fire damp") with the coal, mining in India is less dangerous than in European coal-fields. There are, however, special difficulties associated with the working of thick seams; fire and subsidences in mines have also proved troublesome problems.

Although coal occurs in India in the later geological formations also, the Damuda series (Lower Gondwana) is the principal source of Indian coal contributing over 80 per cent of the total Indian production, now about 66 million tons per annum. The principal coalfields State-wise are:

Andhra: In the Godavari valley of Adilabad, Karimnagar, Warangal, Khammamett, East Godavari and West Godavari districts have an area of 4,000 sq. miles of Gondwana formations with possibilities of workable coal-seams. Rough calculations estimate about 1,000 million tons of coal in this belt. The actual workable collieries producing non-coking coal[1] are situated at Tandur, Singareni and Kothagudem. These are the southern-most coalfields of India and a source of coal supply to most of South India. In large tracts of Godavari valley, since the coal-bearing rocks are hidden under the Kamthi sandstone and allu-

[1] The Regional Research Laboratory at Hyderabad is examining the possibilities of low temperature carbonisation of this coal.

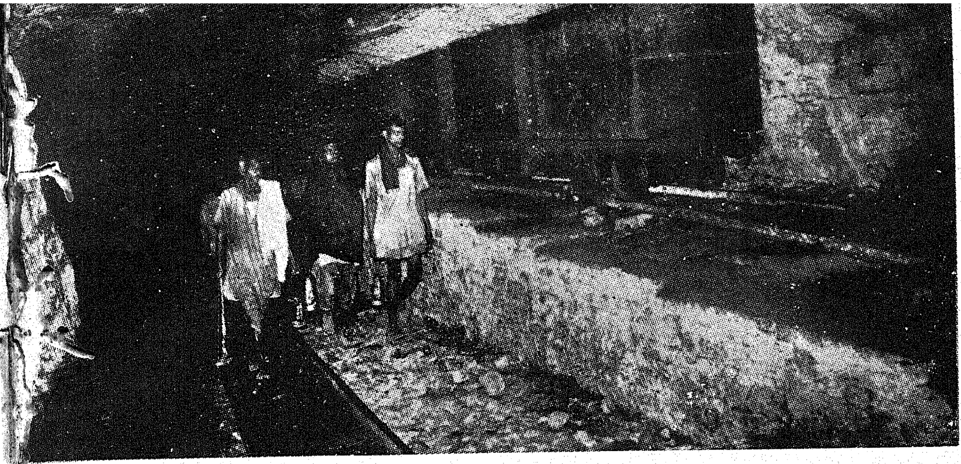
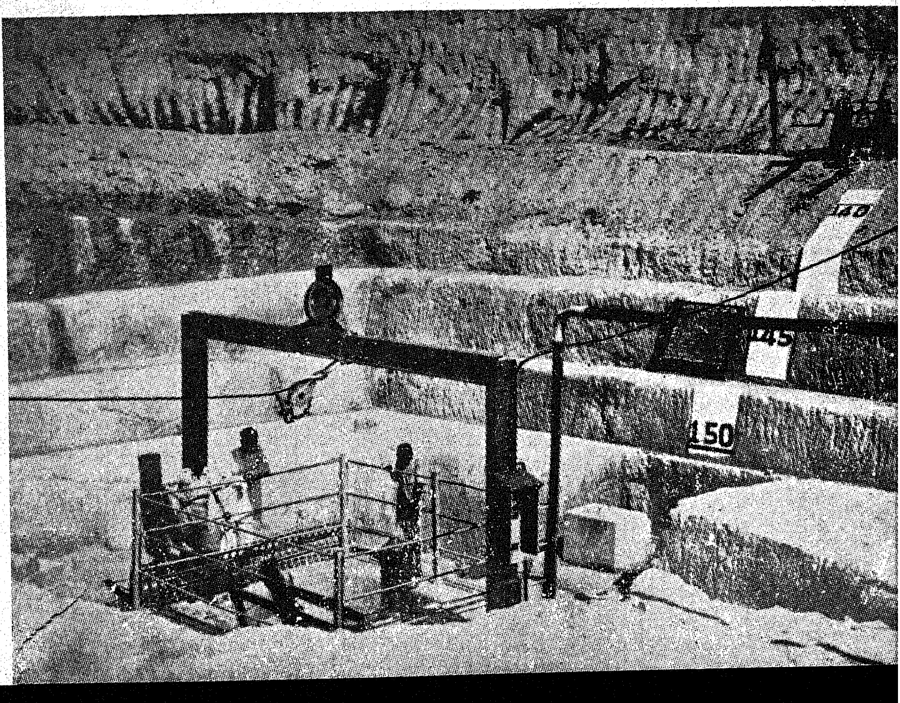


Fig. 1. An Interior View of a Coal Mine, Raniguni

Fig. 2. View of the Open-cast Working of Lignite Mine, Neyveli



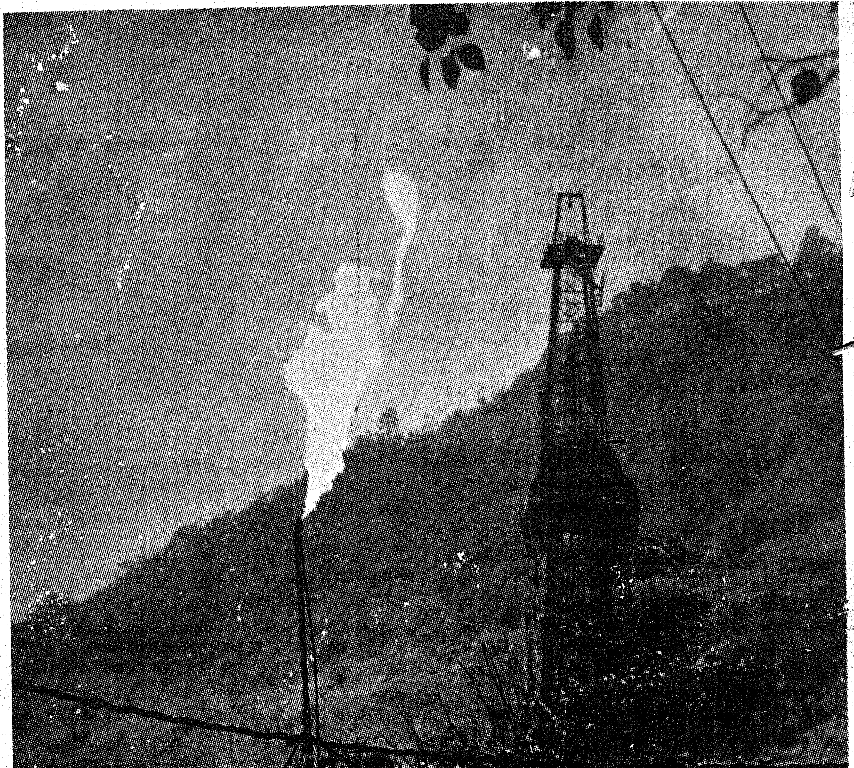


Fig. 3. DRILLING AN OIL-WELL; BURNING GAS AT THE DRILL-SITE, JWALAMUKHI

vium, intensive deep drilling is essential for locating hitherto unknown seams.

Assam: Garo Hills: The coal-bearing areas include the closely associated Baljong, Doigring and Waimong (Chitmang) fields lying east of the Simsang Valley. The two seams in Baljong and Doigring and three in Waimong are all of good quality. The reserves in the lower seams are computed at somewhat over four million tons in Baljong and one million tons in Doigring. On the Asilagaon hill there are large occurrences of at least two coal seams out of which the lower one has reserves of not less than 5 million tons of partly coking coal.

Other promising areas for workable coalfields are the Khasi, Jaintia and Mikir hills.

Upper Assam: The coal-bearing rocks cover a tract of about 50 miles in N.E.F.A. (Lohit Frontier Division). In N.E.F.A. coal measures are found in Namphuk and Namchik river valleys. In all cases the workable seams are exposed along the northern flank of the Naga-Patkoi ranges facing Sibsagar and Lakhimpur districts. Individual coal seams vary in thickness at places from 10 feet to 60 feet. A good quality 10 ft. thick seam has recently been encountered at Nahorkatiya at a depth of a little under 10,000 feet during oil-drilling operations.

Bihar: There are twenty-one promising coalfields in Bihar of which 3 are in Dhanbad, 7 in Hazaribagh, 3 in Palamau and 8 in Santhal Parganas district. Amongst these, Jharia, Bokaro, Giridih and Karanpura are the most important. Lying south-west of Dhanbad town and covering an area of 175 square miles, working at seams of over 4 feet thickness each, the Jharia coalfield has been recognised as the store-house of the best metallurgical coal in India. Detailed drilling carried out by the Geological Survey of India reveals an estimate of the order of 12,000 million tons of *in situ* coal upto a depth of 2,000 feet. Whereas this estimate includes all grades of coal, the total estimated reserves of coking coal are placed at 2,000 million tons.

The Bokaro coalfield forms a narrow but long strip in the catchment of Bokaro river. The 100 feet thick Kargali coal-seam

in east Bokaro, bearing abundant quantities of coking coal, is the chief source of coke for the steel plant at Rourkela. West Bokaro has about 9 important seams ranging in thickness from 12 to 36 feet. The estimated reserves of coal within a depth of about 1,000 feet are of the order of over 600 million tons. To the south-west of Giridih in Hazaribagh district lies the Giridih coalfield also known as Karharbari coalfield. Its field are of 11 square miles has 3 main seams of varying thicknesses: (i) the Lower Karharbari, (ii) the Upper Karharbari and (iii) the Badhua seams, of which the 10-24 feet thick lower Karharbari provides the finest coking coal in India for metallurgical purposes. The recoverable reserves of good-quality coking coal in the field are estimated at about 17 million tons.

The Karanpura and Rampur coalfields lie to the west of Bokaro and cover an area of about 600 square miles. Detailed work carried out by the Geological Survey of India in some blocks of this field with a view to estimate reserves for the 'public sector' tends to put them at 6,000 million tons.

Himachal: Suket, Mandi and Sirmur areas show small seams of low-grade coal with possibility of their use as fuel for brick kilns, lime-burning, etc.

Jammu & Kashmir: This area known hitherto as coal-less has lately been found to contain fuel deposits of considerable size belonging to Pliocene or even newer age.

In Riasi district, coal, some of anthracite quality, occurs in some widely distributed seams of 1-20 feet thickness in association with Nummulitic strata. They are spread over 36 miles of country in three or four coal-fields.[1] Coal seams exposed in Kalakot, Metka, Mabogala, Chakar, Dhanswal-Swalkt, Ladda and Chinkah regions have so far remained unexamined.

Madhya Pradesh: Coalfields of varying size and quality are situated in the following groups of locations:

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[1] Middlemiss has estimated the quantity available at 100,000,000 tons with mining at ordinary depths. Some of the Riasi semi-anthracites contain 60-82 per cent of fixed carbon.

1. Umaria, Korar, Sohagpur (about the largest), Johilla river and Singrauli.
2. Tatapani, Ramakola, Jhillmilli, Bisrampur, Jhagarkhand, Kurasia, Koreagar, Lakhanpur and Rampur, Sarguja district.
3. Damhamunda, Sendurgarh, Rampur and Korba, Bilaspur district.
4. Mand river and Raigarh, Raigarh district.
5. Mohpani-Gotitoria area, Narasinghpur district.
6. Pench valley and Kanhan valley, Chhindwara district.
7. Patakhera, Dulhara, Shahpur and Sonada, Betul district.

Maharashtra: Coal deposits are worked in the Kamptee coalfields in Nagpur district, Wardha valley coalfields in Chanda district, at Bandar, Warora, Majri, Rajpur, Ghugus and Ballarpur in Yeotmal district. Reserves of coal in Wardha valley are estimated at 1400 million tons. Promising reserves of coal have lately been located in the Nagpur area.

Orissa: In Sambalpur and Sundargarh districts lies the Rampur-Himgir coalfield of an area of 520 sq. km. (about 300 sq. miles) one tenth of which possesses the estimated reserves of about 100 million tons of non-coking coal.

Extending from Talchir in the east to Rairkhol in the west, the Talchir coalfield in Dhenkanal and Sambalpur districts covers a total area of about 390 sq. kms. Two workable seams of coal have been brought to light by prospecting by drilling in an area of 29 sq. kms. near Talchir town. The estimated reserves of Talchir colliery, owned by the Government of India, are about 44 million tons.

Uttar Pradesh: Some of the coal-seams mentioned as occurring in Madhya Pradesh are also found here. A small portion of the Singrauli field falls within Mirzapur district. A 4-5 ft. thick high-grade coal seam is known to occur near Kotah. Recent exploratory drilling by the Geological Survey of India in the adjoining portions included in Madhya Pradesh have proved two

thick seams-the upper (70-90 ft. thick) and the lower (50-69 ft. thick). The reserves of coal proved so far exceeds 674 million tons.

West Bengal: The coal deposits are distributed within Burdwan, Bankura, Purulia, Birbhum, Darjeeling and Jalpaiguri districts, the chief coal-producing area being Ranigunj, the first coal-field to be worked in India. The major part of Ranigunj coal-field lies within the State of West Bengal, a small part lying in Bihar. Its area of about 600 sq. miles covers Burdwan, Bankura and Purulia districts, which possess two major coal-bearing horizons in the lower series producing good coking coal; the upper series, consisting of nine coal-bearing horizons, in which the productive seams are Dishergarh and Sanctoria yielding excellent gas-coal. This coal, mixed with coking coal of the lower series, makes hard metallurgical coke. Recent investigations carried out by the G.S.I. in the Purulia area have revealed the presence of Dishergarh seam at a depth of 1800 feet in the Neturia area of Purulia district and in the Salanpur and Kulti areas of Burdwan district.

In Darjeeling district patchy occurrences of coal are recorded in Dalingkot coalfield; several seams occur near Tindharia where the best seam is about 11 ft. thick. In Jalpaiguri district, a few seams are located near the Duars area.

Production of Coal in India

Within the last 45 years India has become an important coal-producing country, the annual production now nearly sufficient for her own requirements. The yearly output from Indian mines rose in 1964 to 66,000,000 tons valued, at the present cost of production, at Rs. 158,00,00,000. Of the post-war output, by far the largest part—83.5%—has come from the coalfields of Bengal, Bihar and Orissa; 9% from the fields of Vidarbha—Madhya Pradesh regions; 3.5% from the fields in Andhra Pradesh and about 2% from the coal fields of Vindhya region. This amounts to a total of 98% of the production of coal from the Peninsula of India. In its geological relations, as stated earlier in this Chapter, the coal of the Peninsula is entirely restricted to the Damuda

series of the Lower Gondwana System of rocks. The remainder of this coal comes from the Lower Tertiary, Eocene or Oligocene rocks of the extra-Peninsula, *viz.*, Assam (Makum), Madras (Neyveli) and Bikaner (Palana). Of these the Assam production is the most important and promising for the future; it averages over 1% of the total Indian produce, while it also approaches Gondwana coal in its quality as fuel. (See Neyveli Lignite.)

The following table shows the relative importance of the various coalfields of India with their average annual output for the year 1960 in round numbers:

GONDWANA COAL

Bengal, Bihar and Orissa	*Tons*
1. Raniganj	15,600,000
2. Jharia	16,800,000
3. Giridih	500,000
4. Bokaro	3,900,000
5. Karanpura	3,350,000
6. Talchir	750,000
Madhya Pradesh	
1. Rewa	1,230,000
2. Pench Valley	2,300,000
3. Korea	1,700,000
4. Umaria	110,000
5. Sohagpur and Singrauli	4,440,000
Andhra	
1. Kothagudam, Singareni, etc.	2,700,000
2. Tandur	310,000

TERTIARY COAL

1. Assam (Makum, Nazira, etc.)	772,000
2. Bikaner (Palana)	60,000
3. Neyveli	3,500,000

Coal thus remains the most important economic mineral product raised in the country and as the figure of good-quality coal, noted earlier in this Chapter, show their proportionately small reserves, several warning notes have been sounded of late regarding the availability of good-quality coal in India and the approaching exhaustion of coking coal for metallurgical use. Recently revised estimates have placed the reserves, easily accessible in the known coal-fields of the country, at about 5,000 million tons of good coal made up of 2,300 million tons of coking coal and the rest non-coking coal.

India's total deposits of metallurgical coal are estimated to be of the order of 4000 million tons. Since only half of this can be economically mined, the actual production can be around 2000–2500 million tons. At an average consumption rate of 20–25 million tons a year, the supply is expected to last about 100 years.

LIGNITE

Lignite or 'brown coal' is a lower-grade fuel which represents the intermediate stage in the alteration of woody matter into coal. Its colour varies from dark to black-brown; it is comparatively more bituminous, friable and pyritous and contains a good deal of moisture and less of combustible matter. The last two qualities make it liable to disintegration on exposure and even to spontaneous combustion.

Its main locations for lignite production are:

Kashmir: The lignite deposits belonging to Pliocene or even a newer age have been found in considerable quantity. Two horizons have been recognised in the Shaliganga river, Ferozepur Nala sector. The upper band is 3 to 6 ins. thick while the lower, about 300 feet below, consists of two or more bands averaging in thickness from 5 to 9 feet. These beds continue further to the north-west in Handwara area.

[1] See Report of the Government Coal Inquiry Committee, 1946, and C. S. Fox's *Memoir on the Lower Gondwana Coalfields*, Mem. G.S.I. vol. lix., 1934 and later publications of G.S.I.

Two well-defined lignite horizons lower down in the sequence occur in the Nichahom area near Handwara in Baramula district, where over a 100 million tons of moderate-grade lignite containing an average 55% combustible matter are easily recoverable from one area near Baramula. Three bands of lignite varying from 3 to 9 feet in thickness have been proved in the upper horizons while another band 5 feet thick occurs in the lower horizon. These horizons continue in the Chokibal area in the Kanahom Nar at Honginkut further to the north-west.

Kerala: While Warkala in Trivandrum district and Paravur in Quilon district do not present any regular seam or bed constituting a workable deposit, lignite occurs as a band, 1½ to 2 ft. thick near Cannanore and in Kasargod *taluk*.

Madras: Lignite usable as fuel occurs with soft waterlogged sandstones and shales. The recently discovered lignite field in Neyveli, in S. Arcot, has added materially to the brown coal resources of India. The active development of this field shows estimated reserves of the order of 2,000 million tons of lignite contained in beds of 10–80 feet thickness, extending over 100 sq. miles. These seams are interbedded with the Cuddalore sandstones of S. Arcot and Pondicherry.

Rajasthan: Extensive deposits of lignite occur at Palana in Bikaner district, where the probable reserves are likely to prove of considerable magnitude. Lignite is reported to occur also in several other places in the same district as well as in other districts of Rajasthan.

West Bengal: Occurrences of lignite of good quality and quantity are reported on the western side of Jainti river, about a mile and a half from Jainti, and in the Buxa hill, N.N.W. of Jainti, while the deposits in Darjeeling and Jalpaiguri districts are in small pockets. Beds of lignite also occur in the Ganga delta.

PEAT

Peat is an accumulation of vegetable matter which has undergone varying degrees of decomposition and carbonisation. It contains a high percentage of water and varies in physical

character from a distinctly fibrous and woody, dark-yellow material to a brown or black jelly-like substance. Although it may be cut from the bog in blocks, peat is seldom sufficiently compact to make a good fuel without compressing into bricks.

The occurrence of real peat is confined to a few places of high elevation. It is found on the Nilgiri mountains at an elevation of over 6,000 feet in a few peat-bogs lying in depressions composed of the remains of Bryophyta (mosses). Peat also occurs in the Kashmir valley in a few patches in the alluvium of the Jhelum and in swampy ground in the higher valleys, where it is composed of the debris of several kinds of aquatic vegetation, grasses, sedges and rushes.

West Bengal: Occurrences of peat beds at depths ranging from 6 to 35 feet have been noted in Calcutta and its suburbs. The peat in Howrah appears to be detrital in character showing that it accumulated in a large marsh or lake which has since been silted up and is now traversed by the Hoogly river.

In the delta of the Ganga there are layers of peat composed of forest vegetation and rice plants. In the numerous *Jhils* of this delta, peat is in process of formation at present and is used as manure.

Deposits of peat are in course of formation in the valley of Nepal, and other places in the Himalayas.

CHAPTER VIII

PETROLEUM AND NATURAL GAS

INTRODUCTION

PETROLEUM IS a liquid hydrocarbon of complex chemical composition of varying colour and specific gravity (0.8—0.98). Crude petroleum consists of a mixture of hydrocarbons—solid[1], liquid and gaseous. These include compounds belonging to the paraffin series (C_nH_{2n+2}) and also some unsaturated hydrocarbons and a small proportion belonging to the benzene group. Petroleum accumulations are usually associated with some gas (methane, ethane, etc.,) called *natural gas*. Mineral oil is generally associated with gas. Some gas seepages may indicate oil at depth; but every gas-seepage may not indicate oil since gas occurs in marshes also. Natural gas is used as fuel and in manufacture of fertilizers.

ORIGIN OF PETROLEUM

While petroleum, like coal, can occur in rocks of any geological age from Cambrian to Pliocene, the most productive petroliferous strata in Asia are of Jurassic to Miocene age.

The oil is found at the summits of anticlines or dome-like folds and is obtained by drilling through the overlying rocks to the summit of the folds. The origin of petroleum is no longer a debated subject; at one time it was thought that it had an igneous origin and the action of steam on metallic carbides was cited as an example of a possibly analogous process. It is now held that oil has an organic origin. This has been established not only by careful consideration of the circumstances in which oil is found throughout the world but also by the presence of optically active

[1] The impure bituminous substance sold in the bazaars as a drug of many virtues (*Salajit*) is a solid hydrocarbon found in the more exposed parts of the higher Himalayas as a superficial deposit. This substance, however, has nothing in common with petroleum, being of entirely different and recent organic origin.

constituents in petroleum. The oil occurrences in India support the view of the organic origin of petroleum from animal or vegetable matter contained in shallow marine sediments, such as sands, silts and clays deposited during periods when land and aquatic life was abundant in various forms, especially the minor microscopic forms of plants and animals. The history of Lower and Middle Tertiary sedimentation in certain deposition centres in India shows that conditions for petroleum formation were favourable. Dense forests and a rich plankton flourished in rich profusion in the gulfs, estuaries, deltas and the land surrounding them during this period. Deposits of this organic muddy sediment in the land-locked sea or estuary or marsh must have precluded oxidation and decomposition of the organic matter, and promoted bacterial and bio-chemical action leading to the formation of various hydrocarbons. Researches show that 60% of organic matter in modern sediment is derived from vegetation. The material which contributes most of this is the shallow-water plankton (floating or free-swimming algae, weeds and other organisms in fresh or sea water). Thousands of feet of diatomaceous beds have been met with in some of the oil-fields.

The degree of porosity of reservoir rocks plays an important part in the underground storage of petroleum. The porosity of rocks may vary from 1 to 5%, in compact strata, and increase to 30 to 40% in some sands and sandstones. A porosity of 20% in a rock would mean a storage capacity of 8,700 cubic feet of oil per acre-foot. If, as is sometimes the case, the reservoir rocks are up to hundreds of feet thick, the oil stored would aggregate up to 1,000,000 barrels per acre.

Mode of Occurrence

Petroleum occurs in the pores and minute interstices of sands and in crevices in limestones, and is always closely associated with sediments, which are of shallow-water, usually marine, origin. The oil is derived from the decomposition of the organic matter contained in the sediments, but the method by which the transformation into petroleum takes place is not yet completely known.

It is evident that there must be special conditions in which there is incomplete oxidation of the carbon and hydrogen, and it has been suggested that the action of bacteria may be a factor in these processes, especially in the elimination of the nitrogen of the animal tissues. It is possible that the change takes place in different stages. At first the petroleum is disseminated throughout the geological formation in which it originated, but the pressure of overlying beds forces it to migrate into the most porous rocks and consequently it is generally found in sand-beds and sandstones intercalated amongst clays and shales, although in some areas it occurs in the fissures and crevices of limestones. It is rarely found without gas, and saline water is likewise often present, associated with the oil. Oil in commercial quantities is not usually found where the component strata are horiontal, but in inclined and folded strata the oil and gas are found collected in a sort of natural chamber or reservoir, in the highest possible situation, *e.g.*, the crests of anticlines. In such positions the gas collects at the summits of the anticlines, with the oil immediately below it. This follows of course from the lower density of the oil as compared with the water saturating the petroliferous beds. "In all cases there must apparently be an impervious bed above to prevent an escape of the oil and gas, and in this there is a certain similarity to the conditions requisite for artesian wells, but with the difference that the artesian wells receive their supplies from above and must be closed below, while the oil and gas wells receive their supplies from below and must be closed above. Both require a porous bed as reservoir, which in one case, ideally, but not always actually, forms a basin concave above, in the other the concave below". When the rocks are not saturated with water, oil may occur in different situations, for example, in the bottom of synclines; but this type of accumulation is unknown in India. The porous sandbeds, sandstones, conglomerates or fissured limestones, which contain oil must be capped by impervious beds in order that the oil be not dissipated by percolation in the surrounding rocks.

Gas

The oil usually contains a large proportion of hydrocarbons which, under normal pressure, would be gaseous, but the pressures prevailing at great depths below the surface are sufficient to liquify these hydrocarbons. In addition, other hydrocarbons (such as marsh-gas) which are not liquified by pressure are readily soluble in petroleum under pressure; in consequence, when the puncturing of an oilsand by drilling into it brings about a great local reduction in pressure, there follows a brisk evolution of gas. This gas, escaping towards the well through the minute crevices in the sand or limestone, carries the oil with it. In this way the oil reaches the well, and if the pressure is sufficient, it will come up to the surface — sometimes with great force. Occasionally a well on reaching an oilsand may get out of control, and the oil flows high above the ground, but care is now taken to avoid waste both of the oil and of the gas which plays so important part in bringing about the production of the oil.

Oil Springs

In the search for oil in India a great deal is made of the existence of surface oil and gas springs. The presence of petroleum springs in an area, while it indicates the existence of subterranean oil, is not necessarily a proof of its existence in quantity. It may as likely prove reverse. A single oil-spring discharging only one pint of petroleum in a day may have, during its whole existence, dissipated at least 12 million tons of petroleum. A multiplicity of oil shows and springs, therefore, may be indicative more of the quantity of oil and gas that has escaped than of what remains underground after the oozing or leakage of ages since its accumulation in the early or middle Tertiary.

Migration

The oil and gas are usually not indigenous to the rocks containing them, but have been concentrated from a fairly large area by the combined effects of gravitation, capillary action and percolation, and underground water. In several cases, the oil

occurs a considerable distance from, or above, the original source.

BY-PRODUCTS

Natural crude petroleum is not used by itself. When refined by distillation, several "fractions", each with distinctive properties are obtained. The ordinary petrol, kerosene, lubricating oil, paraffin, wax, asphalt are some of the products. A number of organic chemicals can also be synthesised for use in industry, such as dyes, plastics, artificial rubber, fertilisers, etc.

PETROLEUM AREAS

Sir E.H. Pascœ has drawn attention to the analogy between the petroleum areas in India and the gulfs or arms of the Eocene sea which were filled up by sedimentation.

The hitherto known petroleum resources of the country are confined to the narrow belts of sedimentary Tertiary strata, which constitute the outer margin of the extra-Peninsular mountains along their whole line of contact with the Peninsular block of the Deccan, from Gujarat, through Punjab and Assam, and thence curving southwards, along the Arakan chain (on both its sides) to the Bay of Bengal. Only the following areas within this belt are considered actual or potential sources of petroleum:

Cambay-Rajasthan-Punjab 'Gulf': The apex of this 'gulf' was at the foot of the Simla Himalayas. From here it widened northwestwards, extending to the Potwar, then curving S.S.W. on the east of the Aravalli, it ended in the Cambay Gulf of the main sea along west Gujarat coast. The valley of the lower Indus has gradually supplanted and succeeded this original Tertiary gulf.

Assam Gulf: This commenced from Digboi and proceeded along the southern side on the Brahmaputra valley, to Sylhet, and along the western flank of Arakan, through Eastern Bengal, to Akyab Gulf. The part southwest of Sylhet is now buried under the alluvium of the Meghna and the delta of the Ganga. The surface indications of oil and gas occur at intervals from the Arakan coast north-eastwards through the Chitagong region to the Surma valley and thence along the north-western side of the Naga hills,

almost to the extreme north-east of the Upper Assam valley. Through vigorous prospecting, four oilfields have so far been discovered, Digboi, Nahorkatiya, Hugrijan and Moran in Upper Assam. In these areas deep test wells put down by the Oil and Natural Gas Commission have shown promise of oil and gas deposits capable of years of sustained production.

The Digboi Field: The oil pools occur along the crest of a sharply folded anticline to the south of the Naga thrust. The productive oilsands in the Digboi field belong to over 20 separate horizons showing much lateral variation. The Digboi oil has an average specific gravity of 0.85 and generally has a high wax content. Digboi's production of petroleum to date is over 8.5 million tons.

The Nahorkatiya Field: A deep well drilled on a structural summit pointed out by a seismic survey in the Brahmaputra alluvium, about 20 miles from Digboi, has brought to light the existence of the new promising oil-fields of Nahorkatiya. Subsequent detailed seismic surveys have shown that the structure of the field is much more complex than was at first thought, the Tertiary strata being cut through by many faults of small and large throw. This new field may have a potential production of 2½ million tons annually. The oil in this area is of mixed paraffin and asphalt base, with an average specific gravity of 0.850 and yielding excellent paraffin, wax, lubricating oil and some bitumen, besides various other by-products.

The Moran field: Drilling has proved an oil-bearing Barail horizon at a depth of 11,000 feet on a faulted dome near Moran some 25 miles southwest of Nahorkatiya. Exploratory drilling is in progress in Moran and adjacent areas in Upper Assam. Moran's potential may be estimated at one million tons per annum. While drilling continues in Upper Assam, extensive geophysical prospecting is being carried out to locate oil-bearing strata elsewhere in the same area under the Brahmaputra alluvium. Other areas that have been under test by the drill are Tripura and Patharia.

Gujarat: Geophysical investigations during the last 10 years

have proved the existence, underneath the alluvium of North Gujarat and the Rann of Kutch, of a wide basin of post-Nummulitic sediments capable of enclosing productive petroliferous horizons, resting upon the faulted surface of the Traps. It stretches from Surat district, across the Gulf of Cambay, to beyond Bhavnagar in Saurashtra. Drilling tests, including off-shore drilling, to establish the commercial possibilities of oil-fields within the Cambay basin are being carried out. The north boundary of the Cambay basin probably extends beyond Ahmednagar and the Rann of Cutch, a considerable distance towards southern Rajasthan, while its southern extent, buried under the shallow water of the Gulf of Cambay, may be much beyond Piram island. The exact reserves of Petroleum in this area have not yet been computed but a probable yield of 2-3 million tons per annum from the existing fields is reasonably expected. Off-shore drilling in this area may considerably enhance this figure. Gravity and seismic methods of exploring the structure of the floor rocks under the Rann of Cutch and some alluvial tracts of northern Gujarat are being employed for further survey of the basin. The Oil and Natural Gas Commission since 1958 has drilled test wells near Ahmedabad at Lunej and confirmed the occurrence of a commercially exploitable oil-field. In 1960, oil was struck in the first well at Ankleshwar, nearly 100 miles south of Cambay town; it has indicated the existence of a new oil-field, capacity 1.8 million tons per annum. Gujarat can, therefore, be reasonably expected to be an oil-producing area of the future.

Jammu and Kashmir: There are possibilities of occurrence of gas and oil in the Jammu region, particularly along the Ravi-Jawalamukhi section.

Madras: A small gas occurrence reported in the Tertiary sediments, buried under alluvium in Tanjore district, lends support to the possibilities of occurrence of petroleum in the Cauvery delta. Test wells are being drilled.

Uttar Pradesh: Geophysical prospecting for oil is being carried out in the vicinity of Bareilly under the Ganges alluvium.

In the world's total annual production of petroleum of

nearly 1450 million tons, India's share has been insignificant; it has hardly averaged 0.6 per cent of the world's total. The annual consumption of nearly 14 million tons, therefore, is made possible by imports from various sources including the Persian Gulf region, Europe and the U.S.A., amounting to 6 million tons.

Potential Sources

There are two other potential oil-bearing tracts in India to which reference may be made, but from which no positive indications have so far been obtained. 1. On the analogy of the great Iran belt of oil-deposits at the foot of the Zagros chain, belonging to the same system of upheavals as the Himalayas, and of the Tertiary sedimentary beds stretching from Jammu to Nainital and, in the Assam foot-hills from the Tista to the Brahmaputra, one can argue the existence of a belt of productive oil-fields in the Himalayan piedmont, chiefly in the Jammu, Kangra and Nepal foot-hill zones.

2. To the north of the Gulf of Cambay and Cutch extend large tracts of central and southern Rajasthan, floored by Mesozoic and Eocene strata. These rocks are covered by desert sands of sub-Recent age and are inaccessible to ordinary geological investigation. Seismic and gravitational surveys are being carried out to map any buried structures suitable for the storage of underground oil and gas.

NATURAL GAS

As explained earlier in this Chapter, Natural gas (chiefly marsh gas with some other gaseous hydro-carbons) usually accompanies the petroleum accumulations. The gas may occur in separate sands containing little or no oil, but most of the natural gas of India is found closely associated with the oil, and supplies the propulsive force which carries the oil from the oil-sands into the wells and, if the pressure is sufficient, brings the oil up to the surface. Since gas is essential for production of oil and is also valuable as a source of fuel on the oil-fields, care is taken to prevent waste of gas which was formerly so common in oil-fields. In south-east

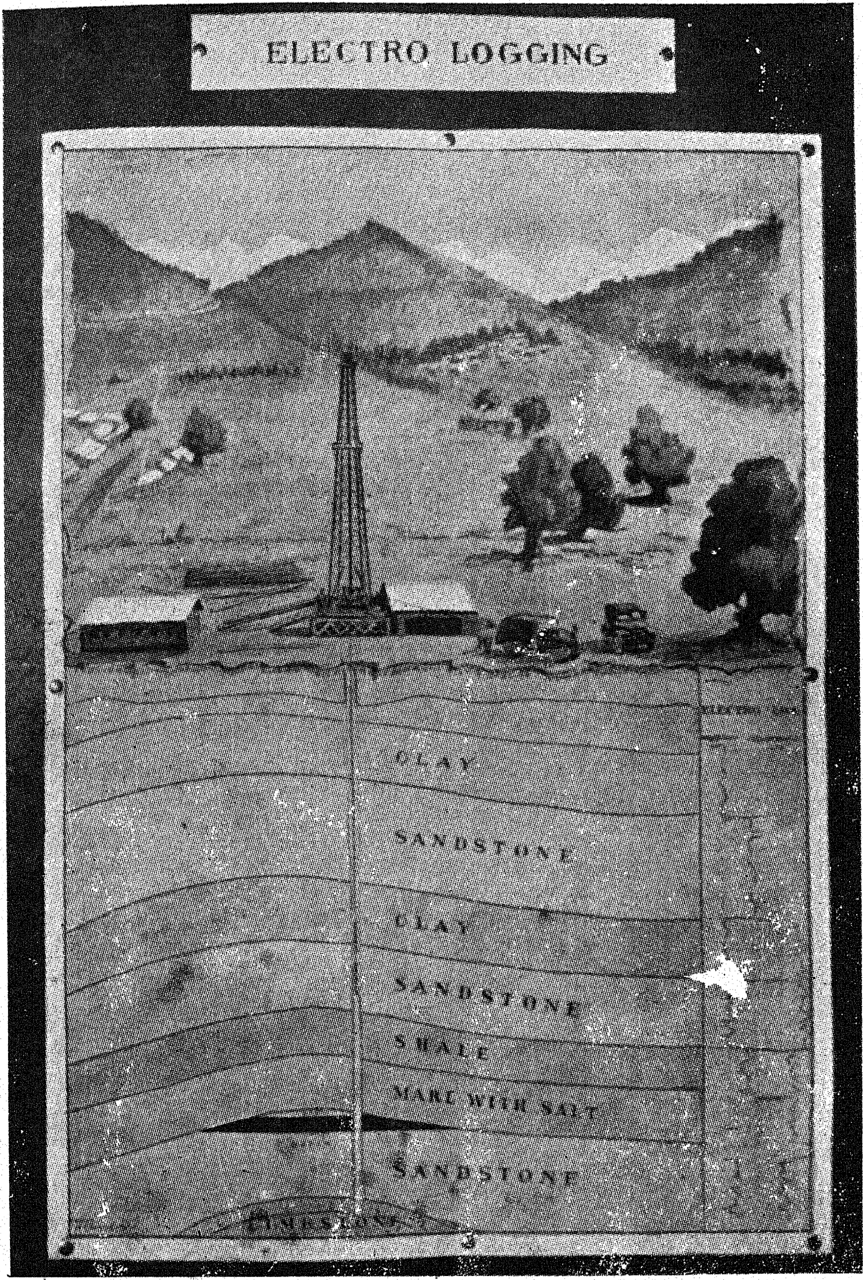

Fig. 4. ELECTRO-LOGGING OF OIL-WELL, SHOWING STRATA PENETRATED BY DRILLING (O. N. G. C.)

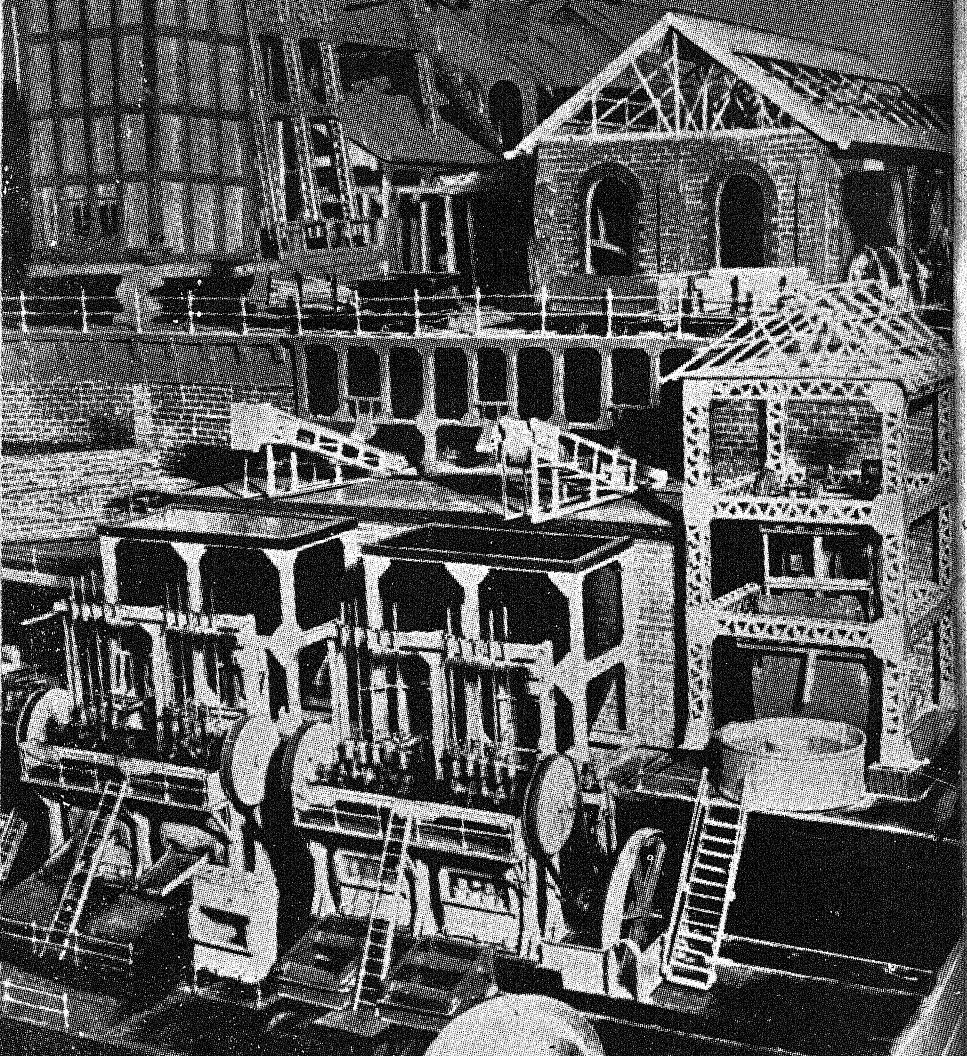

Fig. 5. MODEL OF THE KOLAR GOLD MINE, SHOWING ORE CRUSHING AND STAMPING MILL

Baluchistan (Pakistan) large reserves of natural gas have been discovered in the Laki limestone, the principal accumulation so far known being in the Sui anticline, some 50 miles north-east of Jacobabad, from which about 35 million cubic feet are being produced daily since 1956. In India, there is no gas-field of the productive capacity of Sui, but the oil-fields in Assam and Gujarat yield moderate supplies of natural gas capable of use in industry. Gas from the Nahorkatiya, Cambay and Ankleshwar fields is being piped for use in factories at various centres in Assam and Gujarat to the extent of several million cubic feet a day. Natural Gas is finding increasing use as fuel and in manufacture of fertilizers and synthetic rubber and chemical products.

"The total production of crude oil in India is now about 3.5 million tons per annum; it is supplemented by imports of 10 million tons, value Rs. 100 crores approximately.

CHAPTER IX

ORES AND METALS

Aluminium

Aluminium metal is obtained chiefly from its ore, known as bauxite, a dehydrated oxide of aluminium, or from aluminous laterite. Diaspore and Gibbsite are also secondary ores of aluminium.

Aluminium has a variety of applications from domestic to industrial. It is esteemed on account of its low density, rigidity and malleability. Besides its use in utensils, it has applications in electricity, metallurgy, aeronautics, paints. It is largely employed in the manufacture of alloys with nickel, copper, zinc and magnesium, which are finding ever-widening applications in automobile, railway, aircraft and other engineering constructions. The wide range of magnesium-aluminium and other light-metal alloys used in industries has, during the last decade, transformed the metal position of the world. The mineral Bauxite (see p. 126) has various uses in refining kerosene, preparation of chemicals, refractories, abrasives, alum and aluminous high-alumina cement. Since the discovery that much of the clay portion of laterite is not clay (hydrated silicate of aluminium), but the simple hydrate of alumina (bauxite), much attention has been directed to the possibility of working the latter as an ore of aluminium.

Though, generally speaking, bauxite is a widely spread mineral in the laterite cap of the peninsula of India and the Assam region, the following locations are particularly noted for production:

Andhra Pradesh: Bauxite deposits occur in Eastern Ghats of Vishakapatnam, East Godavari and West Godavari districts.

Gujarat: Large deposits of bauxite occur in Jamnagar district. It is also known to occur in Khera, Broach and Surat districts and along the coastal strip forming parts of the districts of Bhavnagar, Junagadh, Porbander and Kutch. A rich deposit has been recorded near Taibpur in Kapadvanj *taluk.* Some portions of the

laterite between Bhilod and Valia in Rajpipla are of aluminous variety; but since the vertical extent of the occurrences are small, they are not important.

Jammu and Kashmir: Extensive surface spreads of mostly hard and dense bauxite (diaspore type) varying in thickness from 4 to 24 feet, are known to occur over the "Great Limestone" along the coal belt of Jammu region. These deposits analysing 60-80 per cent Al_2O_3 have been discovered in association with the Nummulitics of Jammu and Poonch, where millions of tons of ore are exposed in the surface strata. Their mode of occurrence also suggests a lateritic origin, *e.g.*, by *desilicification* of large, sub-aerially exposed spreads of infra-Nummulitic clay-beds on a series of low, gently inclined dip-slopes. Over 1.8 million tons of high-grade bauxite is estimated to occur in one locality. But though there are large and easily workable deposits, the ore is found to be highly refractory and not amenable to usual methods of treatment for the extraction of aluminium.

Bihar: Extensive deposits of bauxite are found in the areas to the west of the Chandwa-Lohardaga-Gunla Road. The estimated reserves of high-grade bauxite (*i.e.*, bauxite containing 50 to 60 percent alumina) in these areas are of the order of 10 million tons. Nearly a third of the known reserves of high-grade bauxite ($Al_2O_3 > 50\%$) in India occurs in this area. The ore is quarried near Lohardaga and is purified at the plants set up at Muri in Ranchi district

Madhya Pradesh: Large deposits of bauxite occur in the districts of Jabalpur, Bilaspur, Sarguja, Shahdol, Jashpur, Balaghat, Mandla, Seoni, Katni and Kalahandi. In the bauxite of some of the hilltops of Balaghat district, the percentage of alumina is 50 to 57. Small occurrences have been noticed in Chhindwara, Drug, Raigarh, Guna, Shivpuri and Gwalior districts, while the important deposits are those found around Katni in Jabalpur district, in the Baihar plateau of Balaghat district, in the Amarkantak plateau stretching between Bilaspur and Shahdol districts and in the Sarguja, Jashpur, Bilaspur region.

Madras: Extensive deposits of bauxite occur capping about

half a dozen peaks including Shevaroyan and Sholaradu in the Shevaroy hills. About six to seven million tons of all grades of bauxite are estimated to occur in the area. Similar bauxite deposits have been recently located by the State Geological Department in the Nilgiri hills.

Maharashtra: Important deposits occur near Radhanagari, Amboli Ghat, Gargotti, Waki, Rangevadi and Udgeri in the districts of Kolhapur. There are some deposits in the Salsett island and Tungar hill area in Thana district. In Colaba, Poona, Ratnagiri and Satara districts, a very low grade of bauxite deposits is found, though the reserves in this area are large.

Mysore: Locations of significant occurrence of bauxite are Bokanur Navige ridge; Karle Hill, 4 miles south-west of Navige; Bailpur, 5 miles N.N.W. of Jamboti; Jamboti ridge; Kalanidhigarh; Mogalgarh plateau; Kasarawada range of hills, 23 miles S.W. of Chandgarh and Rajhansagarh. The ore contains over 53 percent alumina. Silica and titania contents are well within permissible limits.

Orissa: Bauxite deposits are known to occur in Kalahandi and Sambalpur districts. However, they are not being worked owing to their inaccessibility. Several small occurrences of bauxite, with alumina about 50 percent or over, are located in Koraput district and in Kashipur area in Kalahandi district. The deposits at Kot in the Khondmals region are estimated to yield about 300,000 tons.

As seen from above, the available supplies of bauxite are large, the better grade averaging 55% alumina, 28% combined water, 8% titania, 6% ferric oxide and below 3% silica. The deposits of bauxite are also widespread in India, the major occurrences being in Bihar, Maharashtra, Madhya Pradesh, Kashmir and Madras. The total reserves so far estimated amount to about 250 million tons of all grades of which 28 million tons are of high grade, *i.e.*, having 50% Al_2O_3. India imports a major part of her requirement of wrought and unwrought aluminium, but there is a good future for this metal in India due to the abundance of raw ore material. Availability of cheap power from the many

projected hydro-electric schemes in the country is sure to give the necessary impetus to aluminium industry. In 1957, the production of India bauxite amounted to 96,750 tons and the imports of wrought and unwrought aluminium into the country during the same period went upto 23,205 tons. The present day output of Indian bauxite is 250,000 tons and is chiefly consumed in cement-making, refinement of oil, manufacture of metal and other uses indicated earlier.

The laterites richest in bauxite are those of Ranchi district in Bihar region and of Gujarat and Madhya Pradesh, especially of Katni and some hill-tops in Balaghat district in which the percentage of alumina is 50 to 58. The other important deposits described above are those of Mandla, Seoni, Kalahandi, Sarguja, Thana, Kolhapur, Mahabaleshwar, Bhopal, Palni hills and parts of Madras area.

The annual production of aluminium in India, however, so far, has remained relatively small (50,000 tons against a requirement of 75,000 tons). With deposits of ore so wide-spread and of such magnitude, computed at about 250,000,000 tons, it is proper that India has launched on a programme of production of metallic aluminium to the tune of 75,000 tons to 100,000 tons per annum.

Antimony

Metallic antimony is tin-white in colour. In the native state it is extremely rare in nature; it mainly occurs as lead-grey stibnite, which is the chief ore—sulphide of antimony.

The chief uses of antimony metal is in the manufacture of important alloys, such as type-metal, anti-friction metals, pewter, etc., and in the preparation of hard "antimonial" lead. Its compounds are used in the preparation of medicines, pigment-making, as a mordant in the manufacture of opaque enamel-ware and in glass and pottery manufacture.

Sulphide of antimony, stibnite, is found in deposits of considerable size at the end of Shigri glacier in the Himalaya province of Lahoul (Kangra), but the lodes are in inaccessible localities.

It occurs there mixed with galena and blende in granitoid gneisses. Stibnite is also found in Vishakapatnam and Hazaribagh; but the production of stibnite from these bodies does not appear to be a commercial possibility unless metallic antimony is extracted on the spot. Small quantities of stibnite and antimony occur in veins in the quartzose rocks in Chitradurga district.

The production of antimony in India is of the order of about 700 tons per annum.

Arsenic

Sulphides of arsenic, lemon-yellow orpiment and red coloured realgar, are rather uncommon minerals. Orpiment occurs in calcareous shales and marble in close proximity to dykes of basic intrusive rock. The chief use of orpiment is as pigment in lacquer work, in the manufacture of insecticides, weed-killers, lead-shots and certain alloys. It is also employed as a decolouriser of glass, in paint manufacture, textile printing, and in pyro-techniques, because of its burning with a dazzling bluish-white light. Some small quantity of arsenopyrite occurs near Darjeeling and in the Bhutna valley, Kashmir. Orpiment and realgar are found in the morain-material of Shunkalpa glacier in the Kumaon mountains, but they possess no economic importance.

Beryllium

Mineral beryl is a silicate of beryllium and aluminium and is the chief commercial source of this valuable metal. It occurs in association with mica in the pegmatite-veins, in crystals which at times weigh upto a ton. The pre-Cambrian rocks of India possess considerable resource in this rare metal of industrial and strategic value, distributed sporadically in pegmatite-veins traversing mica-bearing rocks. Beryl is the principal source of beryllium metal (10—14% BeO) which is lighter than aluminium; when alloyed with copper, the alloys develop a high tensile strength and ability to withstand repeated stress. Its main industrial use lies in the manufacture of copper—beryllium alloy and in atomic energy development.

Bihar: Bihar is the principal producer of beryl in India. It is found in mica-pegmatites. Large quantities of beryl are recovered from the mica belt in Hazaribagh and Monghyr districts in the course of mica-mining.

Madras: Beryl is found in the mica-mining area in Salem district, at some places in Coimbatore district and Nellore. A large quantity of beryl has been recovered from Idlapati.

Rajasthan: This used to be the principal beryl-producing State in India. Beryl occurs in the mica-mining areas of Ajmer, Jaipur and Udaipur. Some of the important beryl workings are located in Ajmer district. Jaipur and Ajmer-Merwara also contain workable deposits of this mineral from which large crystals, upto two feet in diameter and weighing upto a ton are sometimes obtained.

Beryllium metal is of great importance in the atomic energy development, because of its property of slowing down neutrons without absorbing them. It is, therefore, extensively used as a moderator in atomic piles and nuclear power Reactors. Its other use is in preparation of special alloys with copper.

During World War II, India exported considerable quantities of beryl from Rajasthan, Bihar and Madras: this quality of beryl is prized because of its 10 to 14% content of BeO, a percentage considerably higher than in beryl from other sources. The production, however, has been fitful and sustained mining for beryl alone is not remunerative enough. Because of its sporadic mode of occurrence in pegmatites, its reserves are difficult to estimate while its output for some years has ranged from 1,000 to 3,000 tons.

Chromium

The principal source of chromium is the naturally occurring ore known as chromite. Chromite occurs as a product of magmatic differentiation in the form of segregation masses and veins in ultra-basic, intrusive rocks like dunites, peridotites, serpentines, etc.

Chromite is useful as a refractory in metallurgy; it can withstand high temperature and, therefore, the bricks made with

ferro-chrome are used in lining furnaces. It is also used in making chemicals, as chromates and dichromates, used in tanning of leather, paint-making, calico-printing and photography. Lead chromate is an essential constituent of many yellow, blue, green and red pigments and mordants. Its chief metallurgical use lies in its being the raw material for the metal chromium.

Modern metallurgy has discovered means of overcoming the problem of rust (hydrated iron-oxide formed by combination of iron with the oxygen and water in the air) by alloying iron with chromium and nickel, a method used in the making of rustless steel and armour plate.[1]

Places of occurrence of chromite as a primary ore of magmatic origin are:

Bihar: Important chromite deposits occur in Singhbhum district. There are sporadic occurrences in Bhagalpur district and near Silli in Ranchi district.

Kashmir: Large deposits of chromite occurring in dunite intrusions forming hill masses have been discovered in the Dras valley of Ladakh and at Burzil in Kashmir.

Madras: A few sporadic and commercially unimportant pockets occur in "Chalk Hills' near Salem. A large deposit of low-grade chromite occurs in Salem district as layers in a belt of corundum-bearing anorthosite rocks south of Sitampundi extending over a large area. Unfortunately, the peculiar chemical composition of this chromite makes it unsuitable for most purposes, without prior special treatment which may make its use uneconomical compared to other deposits.

Maharashtra: The known chromite deposits occur in Ratnagiri district and near Pauni in Bhandara district. In both the areas the chromite is of low grade and will have to be beneficiated, *i.e.*, concentrated from the gangue.

Mysore: Chromite occurs in veins, lenses and as segregations between Mysore and Nanjanagud. In Hassan district, there are

[1] The Ashoka Pillar at Kutab Minar in Delhi is a specimen of rustless iron, the technique of which must have been known in ancient India.

a number of occurrences. The ore is massive, friable and contains 48 to 50% chromic oxide. Contribution from Mysore to the Indian production of chromite is about 11,000 tons.

Orissa: High-grade deposits are situated in the Keonjhar, Cuttack and Dhenkanal districts. In Keonjhar district, the deposits stretch over a length of about 1½ miles at Nausahi. The lodes consist of massive chromite and are upto 50 feet in thickness. The proved reserves are 0.2 million tons of ore with over 48% chromium; the probable reserves may be many times more. The Cuttack-Dhenkanal chromite belt runs for 30 miles in Cuttack district by way of Dhenkanal. The proved reserves here are of the order of 0.43 million tons. During World War II, Ordnance factories used a part of the output for the manufacture of ferro-chrome. The maximum Indian production in late years was 88,000 tons, a good part of the production is being used locally for manufacturing furnace-bricks, other refractories and chemical products; the rest is exported. In 1954, the world production of chromite exceeded 3 million tons, a tenth of which was supplied by India.

The minimum total reserves of all grades of chromite in the country may be estimated at 1,320,000 tons. With the country's developing steel industry, more chromite is expected to be utilised within the country in the production of ferro-chrome, other alloys and refractories. This should entail the necessity of upgrading the lean chromite ores to standard grade.

CHAPTER X

ORES AND METALS (Contd.)

Iron

Iron is a metal of universal use. The farmer's plough is fitted with iron blades, he cuts wood with an iron axe and the wheels of his bullock cart have iron tyres. Throughout the ages the village blacksmith has met the iron demands of the community. But modern demands on this metal have increased tremendously. Its uses have increased thousand-fold since man discovered steel. Steel with its greater strength is required for most purposes of construction, machinery and transport. There is a wide variety of special steels to suit special purposes, such as fatigue and acid-resisting steels, hard steel for machinery tools, stainless steel and other special steels for defence weapons. Iron is extracted from its ores, haematite and magnetite, which are oxides of iron. When these are smelted with coke, the combined oxygen is separated and metallic iron is obtained. To meet the demands of a modern iron and steel works, there should be, in its vicinity, good quality of coal and good limestone and refractories all of which are essential raw-materials for iron smelting.

Occurrence

Iron-ore occurs on a large scale in India, chiefly in the form of oxides: haematite and magnetite. It prevails especially in the Peninsula, where the crystalline and schistose rocks of the Dharwar and Cuddapah systems enclose at some places ferruginous deposits of extraordinary magnitude. Among these massive outcrops of haematite and magnetite of the dimensions of whole hills are not unknown. But the most common mode of occurrence of iron is as laminated haematite, micaceous haematite and haematite-breccia; laterite; lateritic haematite also forms large deposits together with haematite—and magnetite—quartz-schists, the

metamorphosed products of original ferruginous sands and clays. The high-grade haematitic ore-bodies of Singhbhum together with those of Bastar, Keonjhar, Bonai and Mayurbhanj are of Upper Dharwar or newer age, the remarkable concentration of the metal iron in them being ascribed to post-Cuddapah metasomatic action; to original marine chemical precipitation of the oxides, carbonates and other compounds of iron; or to volcanic action and other agencies. These orebodies, many of them containing 60—68 % of iron, are thought to be among the largest and richest deposits of iron in the world, surpassing in magnitude the Lake Superior (USA) ores. They are now estimated to contain about twelve thousand million tons of metallic iron.

The Damuda series of Bengal holds valuable deposits of bedded or precipitated iron-ore in the ironstone shales. The Deccan Traps on weathering, liberate large concentrates of magnetite sands on long stretches of the sea-coast. Iron is a prominent constituent of laterite, and in some varieties the concentration of limonite or haematite becomes so high that the rock can be smelted for iron. In the Himalayas likewise, there occur local deposits of this metal in the Purana formations as well as in association with the Eocene coal deposits.

Iron seems to have been worked on an extensive scale in the past, as is evident from the widely scattered slag-heaps which are to be seen in many parts of India. The iron extracted was of high quality and was much in demand in distant parts of the world. The fame of the ancient Indian steel, *Wootz*—a very superior kind of steel exported to Europe, in days before the Christian era, for the manufacture of swords and other weapons—testifies to the metallurgical skill of the early workers. The geographical distribution of deposits of iron ore is as follows:

Andhra Pradesh: Haematite occurs in Dharwar quartzites and in Cuddapah sandstones and quartzites. At present the Appalanarasimhapuram (Khammamett), Chabali (Cuddapah) and copper mountain deposits (Anantpur district) are being actively quarried mostly for export purposes. The largest of the deposits is the Ongole-Gundlakamma group of deposits, but being of poor quality

cannot be used in indigenous industry unless beneficiated. The same is the case with the magnetite and haematite ores associated with Dharwars in Chittoor, Nellore, Karimnagar, Warangal, Khammamett and Adilabad districts.

Assam : In the early days, iron was smelted from ironstone nodules, thin ferruginous bands and impure limonite, found in the rocks of the Barail and Tipam series. These contain 23 to 40% of iron. Old workings are found in certain areas of Upper Assam, Naga Hills and in the Shillong plateau. Reported occurrences of haematite-bearing quartzite from Khasi Hills are yet to be investigated.

Bihar : The first blast-furnace in Jamshedpur came into operation in 1911 and since then the Tata Iron and Steel Company has rapidly expanded. The iron-ore of Singhbhum and Bonai is of the highest quality and the reserves available are immense and would last for hundreds of years. In Singhbhum district the most important group of iron-ore deposits forms a range nearly 30 miles long, extending from near Gua to near Pantha in Bonai, Orissa. There are three or four parallel ranges to the north of Gua containing high-grade iron-ore. Other deposits in Singhbhum include those in Budhu Buru, Kotamati Buru and Rajori Buru. The well-known Noamundi mines are situated at Kotamati Buru. The estimated reserves of iron-ore in Singhbhum and adjoining area of Bonai and Keonjhar, occurring at the surface and capable of open-cast mining alone, are computed at over 8,000 million tons. The iron content of the ore ranges from 60 to 69%.

Himachal Pradesh : Small quantities of iron-ore are found at several places in the Himalayas. These were being worked by indigenous methods for local use. Some high grade ore occurs in the hills at Thanag in Chachiot sub-division of Mandi district. Extensive deposits of magnetite with haematite occur as bands in schists and quartzites in Koti Kohar ridge at Kohar Khas but the concentration of the ore is so low that it cannot be exploited economically.

Kerala : Ferruginous laterites, about 20 ft. thick, are found near Adatt and Velanganur near Trichur in Trichur district.

They contain about 30 to 40% iron. Lateritoid limonitic iron-ore also occurs in the Kunnatnad *taluk* in Ernakulam district. Samples from this area contain about 55% of Fe_2O_3. Similar lateritic ores are also reported in Kasaragod *taluk* of Cannanore district near Perdal and Bela. There are also iron ore occurrences in Ernad *taluk* of Kozhikode district at Porur, Chembreri, Pandikad, Karivarikundu and Wandur. Magnetite occurs at Nadurvallur of Kozhikode *taluk* in Kozhikode district.

Madhya Pradesh: The iron-ores are widely distributed, the prominent deposits being those of Drug and Bastar districts. In Drug district, deposits occur banded with haematite-quartzite in the Dondi-Lohara area, where they stand up as conspicuous hillocks forming the Dhalli-Rajhara range lying about 40 miles south of Rajnandgaon Railway Station. In Bastar, rich deposits of haematite occur in the Bailadila range, Rowghat and other hills. The reserves of high-grade ore, containing over 65% iron, in Drug and Bastar districts are very large, the available estimates being of the order of about 4,000 million tons. Iron-ore, mainly consisting of haematite, is found in Nimar and Hoshangabad districts. At Omarpani near Tendukhera in Narsinghpur district, both haematite and limonite occur irregularly distributed in fissures and hollows among the limestones and quartzites. Iron-ore has been found near Hirapur in Banda *Tehsil* of Sagar district and in some places in Gwalior, Indore, Dhar and Mandsor districts. Lateritic iron-ores are abundant near Katni, Bijori and Kanhwara hills in Jabalpur district and are found to a restricted extent in Drug district. Ironstones have also been reported near Kodoloi in the Raigarh-Hingei coalfield in Raigarh district.

Madras: There are several large deposits of iron-ores in Salem and Tiruchirapalli district, the more important being in Kanjamalai, Chitteri, Gondumalai, Kollaimalai and Tirthamalai hills. The reserves of iron-ore in these areas are of the order of 304 million tons, containing 35 to 40 per cent iron. The ores are mainly mixtures of magnetite and quartz. Similar magnetite ores are reported to occur in Gopichettipalaiyam *taluk* of Coimbatore district, while magnetite-quartzites occur in many parts of

Madurai, Tirunelveli, Ramanathapuram, South and North Arcot districts. A new iron-ore deposit has recently been located in Nilgiri hills. Because of their low iron content and want of coking coal, these are not of commercial importance. Efforts are being made to utilise the Salem iron-ore by a new process using the lignite of Neyveli.

Maharashtra: In Maharashtra important deposits are met with in Chanda and Ratnagiri districts. In Chanda district deposits of iron-ore occur at Lohara, Akola, Dewalgoan, Biassi, Pipalgaon, Puser and Ratanpur, with total estimated reserves of the order of 22 million tons. The ore is massive and contains between 61 to 71 per cent iron. In Ratnagiri district, the deposits are in the 1½ mile long, low-lying hills facing the Arabian sea near Redi. Massive, spongy and powdery types of ores occur here, associated with banded haematite-quartzites. Similar deposits also occur near Aravalli, Aros, Tiravada and Ajgoan. Detailed prospecting of these areas is likely to prove the existence of workable deposits. Lateritic iron-ores with high iron content are found in Ratnagiri, Kolaba, Kolhapur and Satara districts. These have not so far been considered economically workable.

Mysore : Iron-ores are widely distributed in Mysore; but the high-grade ore deposits are those of Kemmangundi in Bababudan hills, Chikmagalur district and in Sandur and Hospet in Bellary district. The iron-ores of Bababudan are almost entirely haematite with some magnetite varying from 50% to 62% iron. In Sandur, rich haematite derived from haematite-quartzite are found as cappings, 100-200 ft. thick, in association with manganese-ores, amounting to some 120 million tons. In the extension of the Sandur ranges into Hospet *taluk*, there are about six million tons of haematite with iron content ranging between 60 and 65 per cent. About two million tons of ore of much the same quality are available in the Copper Mountains southwest of Bellary. The magnetite-quartz rocks of Maddur-Malavalli of Mandya district have been estimated to contain 41½ million tons with an iron content between 40 and 50 per cent. Iron-ore of inferior quality occurs in Sargul, Kunigal, Hariyur and Shankargudda areas. Some high-grade

iron-ores have recently been located near Mangalore on the West Coast for export to Japan.

Orissa: The most important deposits occur in Sundargarh, Mayurbhanj, Cuttack, Sambalpur and Koraput districts and in Keonjhar area. India's richest haematite deposits are located in the U-shaped Barabil-Koira valley. Nearly 100 deposits with a total area of 20.46 sq. miles occur in this region. About 20 miles of the 30 mile long main iron-ore range, extending from Gua in Bihar to Rontha in Bonai, falls in Orissa. This range is capped for the most part by massive haematite deposits except for a few short breaks. Other large deposits are situated on the eastern and the southern sides of the valley. The deposits consist of high-grade ore with iron content varying from 55 to 68 percent. The proved reserves in this area are of the order of 4,500 million tons. Some of the deposits worked by the Tata Iron and Steel Co. Ltd. are the high-grade iron-ore bodies occurring in Mayurbhanj district at Gorumahisani, Sulaipat and Badampahar. The Gorumahisani deposits are estimated to contain about 20 million tons of ore. The Sulaipat deposit reserves are calculated to be about one million tons. Most of the ore mined has more than 68% iron content. The Badampahar deposits consist of a large amount of float ore bodies. The reserves are about 31 million tons. The deposits on Gandhamardan Pahar, about 10 miles west of Keonjhargarh, have reserves of about 30 million tons of ore with over 60% iron. Scattered deposits of haematite occur in a 7 mile long belt in the Tomaka range between Patwali and Kansa in the Sukinda area of Cuttack district. Further west, high-grade iron deposits occur on Daitari hill along the boundary between Keonjhar and Cuttack districts. The total reserves are of the order of 100 million tons. In the Hiraput hills, 6 miles west of Umarkot in Koraput district, there is a minimum quantity of about 10 million tons of ore with 60% iron content. The largest deposit in Sambalpur district is in Nalibassa Hill which is estimated to contain about 15 million tons of ore. Large deposits of vanadiferous and titaniferous magnetite occur along the marginal hill of the Sunlipat region in Mayurbhanj and Balasore districts. The total reserves of these are of the order

of 20 million tons. In Orissa State, the total proved and indicated reserves of iron-ore are of the order of 2,253 million tons.

Punjab: Ore bodies of magnetite and haematite run from Chhaperi to Jaunpur. At Antri in Mahendergarh district, the ore contains 57.4% iron, where the reserves, upto 300 feet, are estimated to be about five million tons. There are minor occurrences at Bir in Kangra district and 3 miles southwest of Muth in Kulu valley.

Rajasthan: Fair reserves of iron ores (haematite and magnetite) are available in Alwar, Bundi, Jaipur and Udaipur districts.

Uttar Pradesh: Iron-ores occur in Lowagoan, Bharnaumi, Chopra, Udatoli and Jalai in Garhwal district which is stated to have been an active mining centre of iron-ores some decades back. Iron-ores are also reported from Mirzapur district.

West Bengal: Local concentrations of haematite are found near Porapahar and of magnetite in the quartz-magnetite-granulites in the area adjoining the coalfield in Bankura district. The occurrences of iron-ore in the northern part of the State include sporadic patches varying from ferruginous clays to impure brown haematite and micaceous haematite found in parts of Darjeeling and Jalpaiguri district. At present these low-grade iron-ores have no utility in the iron industry. Good quality iron-ore (free from sulphur and phosphorus) is reported from Samalbones. Iron-ores have been reported from Buxa-Bazaar in Buxa-Duars area of Jalpaiguri district. But due to transport difficulties, this commercial utilization is hampered. In West Bengal there are two big iron and steel industries, one at Durgapur and the other at Burnpur.

It can be gathered from the above that in South India the most important deposits consist of those of Salem, Madurai, Mysore (Bababudan Hills), Cuddapah and Kurnool, while Singhbhum, Manbhum, Sambalpur, Bastar and Mayurbhanj are the iron-producing districts of Bihar and Orissa. In Bengal proper, the Damuda ironstone shales contain a great store of metallic wealth, which has been profitably worked for a long time, both on account of its intrinsic richness as well as for its nearness to the chief source of fuel. In Assam also iron occurs with coal. In Madhya Pradesh the most remarkable iron deposit is that of Chanda district, where

the entire body of the 250 ft. high hill of Khandeshwar is iron-ore. Jabalpur, Drug, Taipur and Bilaspur have likewise large aggregates of valuable haematitic ores which have been so far prospected only in part. In Maharashtra the chief sources of iron are laterite and the magnetite sands of rivers draining the trap districts, both of which are largely drawn upon by the itinerant *lohars*. Important reserves of high-grade ores of Dharwar age are met with in Goa and Ratnagiri (which are now largely drawn upon for export), with low percentage of silica and of phosphorus below the Bessemer limit. In the Himalayas, the Kumaon region and Riasi district, Jammu hills supported local furnaces for the manufacture of munitions of war during the last two centuries.

It has been noticed that the iron-ores are mainly haematite, magnetite and limonite, but the working ore-bodies are largely mixtures of haematite with subordinate limonite. India is thus endowed with very large deposits of iron-ore and other necessary raw material to enable her to become one of the most important producers of iron and steel in the world. According to recent estimates, the total Indian reserves of better-grade iron ore are probably as much as 21,000,000,000 tons. In contrast with the vastness of ore reserves, however, the annual production of pig-iron and steel in the country yet remain small, barely 7 million tons. The expansion of the steel industry is being brought about in a planned way and the production is accordingly expected to increase rapidly. Annually India imports iron and steel materials (hardware, machinery, railway plant, bars and sheets, etc.) to the value of nearly 150 crores of rupees. At present India produces 14.5 million tons of iron ore, manufactured products of which are: pig-iron 5 million tons, valued at 14 crores of rupees; finished steel 5,500,000 tons, valued at 100 crores of rupees and ferro-manganese about 70,000 tons, valued at 7.5 crores of rupees. Rest of the ore is exported. Given the fullest scope, the iron and steel industry in the country should envisage a commercial-scale manufacture of a range of ferro-manganese and other ferro-alloys, *e.g.*, ferro-chrome, ferro-silicon, ferro-titanium, ferro-tungsten, ferro-vanadium. These are being planned at the existing and projected Steel Works at

Jamshedpur, Burnpur, Bhilai, Durgapur, Rourkela and Bokaro.

Lead and Silver

Lead is a soft but heavy metal. Modern civic amenities require lead-pipe for sanitary fittings; but the most important industrial use of lead is as a constituent in alloys, such as type-metal, bronzes and anti-friction metal. Lead oxide is used in lead sheeting, cable covers, ammunition, glass-making and rubber industry. Lead-oxide paints are used extensively in painting ships to prevent rusting. Lead nitrate is used in calico-dyeing and in printing processes. Lead does not occur free in nature; it occurs as a cubic sulphide known as galena. Both sphalerite (sulphide of zinc) and galena occur associated together in nature. Galena characteristically breaks into small cubic pieces if hammered. Lead was formerly produced in India on a large scale, though very little lead is now produced in the country. Large mounds of slag, found in Mewar, Jaipur and in parts of Bihar, indicate that a considerable amount of ingot-lead was produced in several parts of the country in medieval times. Ores of lead, chiefly galena, occur at a number of places in the Himalayas, Madras, Rajasthan and Bihar, enclosed either among the crystalline schists or, as veins and pockets, in the pre-Cambrian and later limestones.

Lead ores are found at following localities:

Andhra Pradesh: Galena occurs at Chityala and Chelima in Kurnool district, Karempudi in Guntur district and Zangamrajupalle in Cuddapah district. The Chityala occurrence is in granites, presumably associated with the fault breccia of quartz. The other occurrences are in shales and limestones of Cuddapah. Galena is also reported to occur near Chintakunta in Nalgonda district and Jestaipalli in Khammam district. The prospects of proving large deposits of galena do not appear bright, but some of the occurrences deserve detailed examination.

Bihar: The lead-ores of Hazaribagh and Manbhum are on a fairly large scale and are often argentiferous, yielding a few ounces of silver per ton of lead. Galena is found in parts of Singhbhum, Ranchi, Hazaribagh and Palamau districts but with little

chance of success in their working. The G.S.I. has taken up investigation in some parts of the State.

Himachal Pradesh: Indications of lead-ore were reported from the village Tal and Samoh in Arki *tehsil* of Mahasu district, but an examination of the site revealed only rolled galena pebbles of varying sizes and no lode.

Jammu and Kashmir: Lead-ore (galena) is known to occur in the Buniyar area, Baramula district, in quartz veins and as stringers in the Salkhala metasediments. Sulphides of iron, zinc and rarely copper are also recorded from the area, where two small ore horizons have been located. Disseminations and veins of galena occur around Nigote in Udhampur district over a length of two miles in the "Great Limestone" formation at shallow depths of 4 to 20 feet below the surface.

Madhya Pradesh: Lead-ores, often argentiferous, are on a fairly large scale, yielding a few ounces of silver per ton of lead. Stringers and nests of galena have been reported to occur in the limestone exposed in the bed of Mahanadi river near Padampur, Bilaspur district. Occurrences have been reported at Ranitalao near Chicholi, Thelkadand Karamatara in Drug district. Galena has also been recorded from Bhelaunda and Chiraikhurd in Sarguja district. Old excavations in the limestones at Jogakhurd in Hoshangabad district have revealed the presence of argentiferous galena. Specks of argentiferous galena have been noticed in limestone in Damoh district and also in association with copper lodes at Sleemanabad in Jabalpur district. Galena occurs as veinlets, patches and specks in the decomposed gneisses at Andar in Shivpuri district and near Kurol in Gwalior district. In the past, however, considerable amount of ingot-lead was produced here for centuries.

Mysore: Lumps of galena were found at Metri, 25 miles N.W. of Bellary during 1951-52; but detailed prospecting by drilling and pitting has shown that the deposits are not of economic importance. Some minor occurrences of lead-ore are known near Ingaldhal in Chitradurga district.

Punjab: Galena occurs at Jari, in Parbati valley, Kulu

sub-division, and at Tabo in Kangra district.

Rajasthan: Galena is found associated with zinc-blende in Zawar mines in Udaipur district operating at the site of the old abandoned mines. The Zawar ores belong, geologically, to the class of metasomatic replacements, an Aravalli limestone, being replaced by the sulphides and carbonates of lead and zinc, by the process of molecular replacement. The total reserves of good ore have been estimated at 734,300 tons containing on an average, 7.16% lead and 7.49% zinc. To this figure must be added eight million tons of low-grade ore containing an average of 3 to 4 percent metal. Lead-ore is also reported to occur near Rikhabdeo and Debari in Udaipur district, Ghughra and Mando in Dungarpur district, Wardalia in Banswara district and Gudha Kishori Das in Alwar district. The lead-ore of Mewar is on a fairly large scale and is often argentiferous, yielding a few ounces of silver per ton of lead. Here again, large mounds of slag found in Mewar in Jaipur indicate the production of the metal in the past. These mines have lately begun to produce 1000 tons of galena and to smelt a few hundred tons of lead.

Uttar Pradesh: Galena is reported to occur at Kharahi in Almora district and Pindki in Tehri Garhwal. The occurrence at Kharahi is a promising one.

West Bengal: Small pockets of argentiferous galena, cerussite and sphalerite occur in the dolomite bands in Buxa Duars area of Jalpaiguri district. Lead-ores occur also in a number of other places in Darjeeling and western Duars area.

Generally speaking, the quantity of lead actually produced in India at present is very little. The Zawar lead-zinc mines near Udaipur have reopened extensive ancient workings for lead and zinc and have exposed promising ore-bodies. The annual production of lead, however, is yet small from these mines—4,000 tons. The annual consumption, about 26,000 tons met from exports. In 1960, 6,000 tons of lead concentrates were produced in India.

Silver

As a precious metal silver has been cherished throughout

the ages. Because of its softness and attractive colour silver plates and jewellery have been valued only next to gold ornaments. Silver coins were used until very recently in India. It is still an important currency metal in many parts of the world. Small quantities of silver are used in electro-plating; Silver salts are used in medicine, photography, for colouring glass, etc. Silver occurs in nature in the free state, as veins, replacement deposits, contact matamorphic deposits, or as alluvial concentrations, being occasionally 90% pure, but generally containing copper, etc.

Bihar: Traces of silver occur associated with lead-ores in parts of Hazaribagh, Palamau, Ranchi and Singhbhum districts.

Himachal Pradesh: Native silver occurs about 2 miles east of Chargoan in the Sutlej valley in Bushaher, but it lies on a dangerous precipice and detailed exploration is not possible without special means of access, due to the necessity of working at altitudes of about 11,000 feet. In practice, however, with the exception of the quantity of silver won from the Kolar gold ores (ranging from 400 kg.) and what is lately being obtained as a by-product from the smelting of Zawar lead-ores (4100 kg. per annum.) no silver is produced in the country. Yet, India being the largest consumer of silver in the world, the extent of its average annual import till recently used to be worth £10,000,000. It has now fallen to Rs. 500,000.

Cobalt and Nickel

Cobalt and nickel ores are not among the economic products of India.

Lately cobalt-ore deposits believed to contain considerable reserves of the metal have been reported from Nepal; a small quantity of concentrate and cobalt speiss (ore averaging 8.7% of cobalt) was exported from Nepal during World War II. But the mode of occurrence, geology of the deposits and probable and possible reserves yet await investigation. The only notable nickel-ore in the Indian region mostly extends into Nepal 40 miles from Kathmandu, where the ore is stated to contain 8% of nickel. Geological examination and detailed prospecting have so far not been

possible to ascertain the quality and extent of the deposit.

The *Sehta* of the Indian jewellers is the sulphide of cobalt used in making blue enamel.

Nickel does not occur free in nature. When iron is alloyed with some chromium and nickel, an alloy known as nickel-steel is obtained. This is the rust-proof "stainless steel" of a superior quality used for making utensils, etc. Because of its greater hardness and tensile strength than carbon-steel, nickel-steel is used in the manufacture of armoured plates, motor-cars, etc. Metallic nickel is used in the construction of certain storage batteries and as a catalyst for the hydrogenation or hardening of fats and oils intended for use in making soap and foodstuffs and in the making of "Vanaspaty" popularly known as vegetable ghee. The white metal-plated utensils and other articles, the familiar Five and Ten Paise coins contain nickel as an alloy. When copper is alloyed with nickel and zinc, "german silver" is obtained.

The following occurrences may be noted:

Jammu and Kashmir: Impregnations of nickeliferous iron sulphides and arsenides are seen in the vicinity of Ramsu. The mineralised zone is over three miles long and about 180 yards broad. Preliminary investigations reveal that richer, workable zones may exist at depth. Small deposits of nickeliferous pyrites, containing 1.7% of Ni, have been found in the Purana rocks of Ramsu and Buniyar and in the Carboniferous limestone (Great Limestone) of Riasi, Kashmir.

Kerala: Nickeliferous pyrrhotite and chalcopyrite occur in the auriferous quartz-reefs of the State, but not of sufficient magnitude to support mining operations.

Mysore: Traces of nickel are known in the lateritic soil and rocks associated with ultra-basic rocks of Byrapur chromite belt in Hassan district as well as the nickeliferous pyrrhotite and chalcopyrite in the auriferous quartz-reef of Kolar. These are not of economic value.

Rajasthan: A sulphide of cobalt and nickel is found in the famous copper mines of Khetri-Jaipur region; but the quantity available is insignificant.

Singhbhum (Bihar): Lately nickel-ore has been found in small but significant proportion associated with uranium-ore in Singhhum, Bihar. If this association proves to be constant and of uniform distribution, nickel mining would be commercially remunerable. Small-scale nickel mining can then be carried out along with the mining of uranium-ore, at present being developed at five or six locations by the Department of Atomic Energy.

In common with other non-ferrous metals, lead, zinc, tin and silver, there is a paucity of cobalt-nickel ores in India. (Imports: Cobalt: 50 tons value, Rs. 1 million; Nickel : 1900 tons, value Rs. 15,500,000).

Copper

As a metal copper came in use of Man much earlier than iron. Being malleable, it can be beaten into utensils of any shape. When alloyed with zinc it is known as "brass" and with tin "bronze" both of which are commonly used for making cooking utensils and other objects of common utility.

In modern times it is widely used for transmission of electricity from power stations to consumers, copper being a good conductor of electricity. Such copper wire overhanging across vast areas of land are familiar sight in all modern developed countries.

Native copper occurs in nature only sporadically, the golden yellow sulphide of copper being more commonly available. These have a coating of green malachite and blue azurite (carbonates) which are copper carbonates formed by alteration of the sulphide. Both malachite and azurite thus often indicate the presence of enriched sulphide below the surface.

Andhra Pradesh: During the Vijayanagar Empire copper-ores were worked in Kurnool, Guntur and Nellore districts. Preliminary geophysical surveys indicate the presence of copper-ore near Yellambailu in Khammam district, Nellore and Krishna districts. Recently completed detailed structural mapping in Ghani, combined with prospecting by drilling, have revealed commercial sources of copper in the State.

Bihar: Copper ores occur along a belt extending for about

80 miles. These copper bearing rocks persist along a zone of overthrust in the Dharwar schists and intrusive granite. The deposits worked at the Mosaboni mines, Singhbhum, consist of sulphide ore assaying around 2.4% of copper, somewhat richer ore shoots have also been noticed elsewhere in the same area.

Besides Mosaboni, well-defined lodes of copper have been worked in Rakha, Surda and Dhobhani mines. Amongst these Rakha and Dhobhani workings have practically gone out of production. An ore reserve of 3,424 million tons containing about 1.49% copper has been proved by the Indian Copper Corporation at Mosaboni and Surda. The ore produced at Mosaboni is concentrated and smelted at the plant situated at Maubhandar.

Copper occurrences are also known at Chhotanagpur, Hazaribagh and Santhal Parganas district. Prospecting by modern methods is being applied to some of these deposits.

Jammu and Kashmir: Copper ores, including sulphides, oxides and carbonates occur in the Shumahar area (Anantnag district) in Lidar Valley in impersistent quartz-veins associated with lead ores. Sulphides and carbonates of copper have been discovered in the Kangan area, Srinagar district, in quartz veins. They merit further investigations. Quartz veins carrying sulphide of copper and iron with some oxides, carbonates and arsenides occur on the Lashtil hill spur, Baramula district. Assay results of the ore indicate presence of gold and silver in traces. Disseminations of copper ore have been noted over a distance of 16 miles from Jangal Gali to Sersandu on Chinab river. The mineralisation is not continuous. Streaks, veins and lenses of copper sulphide are noted in the Dul neighbourhood, Doda district which merit further exploration.

Isolated masses of pure native copper have been found in the bed of the Zanskar river, but their source is unknown. They occur there as water-borne nodules weighing upto 22 lbs.

Kerala: Besides sporadic occurrences of native copper, chalco-pyrite occurs in Vadavathur, about 3 miles east of Kottayam. Copper ores are reported to occur near Punalur in Quilon district, though their economic possibilities are not yet known.

Madhya Pradesh: Of the copper-ores reported from several localities, only Sleemanabad in Jabalpur district offers possibilities of economic extraction.

Madras: The Geological Survey of India has recently located some copper-lead-zinc deposits near Mamandur in South-Arcot district which shows evidence of some old workings.

Mysore: Quarries in Chitaldrug district in the vicinity of Madur in Bangalore district, Kalyadi in Hassan district and Chikamagalur district, indicating small deposits of copper-lead-zinc ores, are so far considered economically unimportant.

Punjab: Old abandoned copper mines are situated at Solan in Simla Hills and at a number of places in the Kulu area. Small amounts of ore have been obtained near Sungam in Kangra district. There are minor occurrences of copper ore at Mothoka and Ghatsher in Narnaul *tehsil,* Mahendergarh district.

Rajasthan: Rajasthan still bears evidence of the flourishing copper industry of India in former centuries when large quantities of copper and bronze were produced from Rajasthan and Singhbhum (Bihar) mines; these sites are indicated by extensive slag heaps and refuse "copper workings". Even within historic times, important copper mines existed in Alwar, Ajmer and Khetri.

At present the important occurrences of copper-ore are those of Khetri, Babai and Daribo in Jhunjhunu and Alwar districts, of which the Khetri deposits are under active investigation and exploration. Here explorations have revealed reserves of over 100 million tons of ore (Cu. 1%). Copper is also reported from Ajmer, Banswara, Bikaner, Bharatpur, Bundi, Udaipur and Tonk districts.

Uttar Pradesh: Copper ores are reported from a large number of localities in Garhwal district. The occurrences at Pokhari, Dandokahan and Kandhara in the same district deserve attention. Many old workings are reported from these places near Dewal Thal and elsewhere in Almora district.

West Bengal: In places in Darjeeling district, chalcopyrite and cuprite (copper oxide) with malachite occur as disseminations.

In the Himalayan region recent work has proved the existence

of workable ore reserves in Sikkim and in some parts of Kumaon and Nepal.

In the overall copper picture, however, the ore occurs in too scattered a condition to be worth working; it is rare that local concentrations have produced workable lodes or viens. (The most common ore is the sulphide, chalcopyrite, which, by surface alteration, passess into malachite, azurite, cuprite, etc.) It is only the copper-ores of Singhbhum and Rajasthan that are concentrated as veins or as disseminations in the Dharwars schists and phyllites. Under these circumstances, the deposits worked with some degree of success are those of Singhbhum district, Mosaboni mines which yield about 450,000 tons of ore per year valued at Rs. 220 lacs. 7,000 to 8,000 tons of refined copper are produced from the ore mined at Mosaboni, so far the most productive copper mines in India.

Copper-Ores of Sikkim

The copper deposits of Sikkim and of Darjeeling district attracted much attention once. In this area valuable lodes of the ore (percentage of copper 3 to 7) are proved to exist in association with compounds of bismuth and antimony, together with ores like pyrrhotite, blende and galena.

With her expanding requirement of copper, India has to import copper of the order of 45,000 tons, exclusive of brass and bronze.

Gold

Gold occurs in India both as native gold associated with quartz-veins or reefs and as alluvial or detrital gold in the sands and gravels of several rivers. More often it gets liberated by weathering and particles of gold get concentrated in river and stream sands at certain places. Such deposits are known as "placer deposits" from which gold is recovered by panning. The principal sources of this precious metal in India, however, are the quartz-reefs traversing the Dharwar rocks of Kolar district (Mysore State) which are auriferous at a few places.

As a precious metal gold has been cherished throughout ages. Because of its softness, colour, lustre and non-tarnishing quality

gold ornaments have been highly valued. From ancient times it has been used for coinage; even where modern national economy has necessitated the removal of the gold standard in coinage, international monetory transactions still presume a backing of gold. Though it is well-known that the major part of gold produced in India comes from the Kolar mines, the position is set down State-wise as follows:

Andhra Pradesh: The occurrence of gold in Chittor district and Ramagiri in Anantpur district is well-known. The abandoned Ramagiri field was worked to a depth of 1,150 feet and was worked till 1924. The total recovery of gold from this area was 1,82,315 ounces. On the basis of the detail mapping done by the Geological Survey of India in recent years, drilling may be commenced to assess the gold potential.

Assam: Small quantities of gold occur in the river sands of Upper Assam. Although gold occurrences have been recorded from several Upper Assma rivers, the Subansiri river bed was the best gold-producing area in Assam in early days. The placers have doubtless been derived from auriferous quartz viens in the metamorphic rocks of north-western Himalayas.

Bihar: Gold has been obtained from the alluvium of the rivers and streams of southern Chhotanagpur. The Subarnarekha (gold-streak) river, as its name suggests, is well-known for the gold content of its sands. After heavy rains the local villagers wash and obtain from the river and stream sands small quantities of gold. However, there appears to be no alluvial gold deposit which could offer scope for large scale extraction by modern methods.

Gold-bearing veins also occur in certain localities in southern Chhotanagpur area, where some abandoned mines are also known.

Himachal Pradesh: The occurrence of small quantities of gold in the sands of the Himalayan rivers is well-known. These alluvial deposits are normally too poor to be worked. Reported occurrence of gold at Chargoan near Urni in Bushaher of Mahasu district were examined but did not prove to be of any importance. However, gold-washing is carried on during the spare days in several rivers in Simla Hills, particularly in Bilaspur district by a group of

people who work the water-mills. The quantity of gold produced is almost negligible, a day's labour winning gold worth a few paisas only.

Jammu and Kashmir: Sporadic gold placers have been recorded in the Kargil area for a long distance along the terraces of Indus river. Concentration occasionally reaches 0.57 tolas of gold per cubic yard of gravel. Some platinum has also been found in these gold washings.

Madhya Pradesh: Gold has been obtained from times immemorial by local gold washers from river sands and gravels from parts of the districts of Balaghat, Bastar, Bilaspur, Jashpur, Mandi, Raipur and Seoni. The only localities where gold has been found in *situ* are Sonakhan in Bilaspur district and Sleemanabad in Jabalpur district, where it has been found in small quantities in copper-ores.

Madras: A few quartz-veins traversing a band of chloritic and argillaceous schists of Dharwar age support the Anantpur field whose yield in 1915 approached 24,000 ozs. After several vicissitudes this mine ceased operations in 1927.

The chief gold-bearing belt is the Wynad gold-field in Gudalur *taluk* of Nilgiri district, where there are old mines and prospects which were opened up during the 1890 and subsequently abandoned. Gold is also known to occur at Bensibetta hill tracts in Gobichettipalayam *taluk* of Coimbatore district and in some parts of Dharmapuri and Krishnagiri *taluk* of Salem district. These areas merit detailed investigation.

At the above and other places in peninsular India, the former existence of gold is revealed by many signs of ancient gold-working in diggings, heaps of crushed quartz and stone mortars, which have (as has often happened in India with regard to other metalliferous deposits) guided the attention of the present workers to the existence of gold.

Mysore: 90% of the Indian gold comes from the State of Mysore. The auriferous lodes of these gold-fields are contained in the quartz reefs traversing the Dharwar rocks of Kolar district. The quartz veins run parallel to one another in a north-south belt of

hornblende-schists along shear-zones. The gold is associated with pyrite, pyrrhotite and arsenopyrite, the ore being hypothermal in origin. The most productive of these is a single quartz-vein, about four ft. thick, which bears gold in minute particles. Mining operations in this reef have been carried out since 1880's to depth beyond 10,000 feet, some of the deepest mining shafts in the world. They have disclosed continuance of the same mode of distribution of the ore in the gangue. Gold is obtained by crushing and milling the quartz. There are ancient mines of gold at Honnali, Lakkavalli, Kempinkote and other places in Shimoga, Chikmagalur and Hassan districts, at Bellary in Tumkur district and at Gadag in Dharwar district which call for further investigation. During recent years the Geological Survey of India has carried out detailed surface and underground investigations in the Kolar gold-field area with a view to locating new lodes.

The annual yield of gold from the Kolar gold-fields once averaged 340,000 fine ounces valued at more than £ 2,000,000. For the last 15 years it has averaged 200,000 ozs.; the production is falling in late years. Besides the difficulties due to increasing depth of workings, the mines are experiencing considerable difficulty from rock-bursts, a problem acutely present in these Kolar Mines.

Next to Kolar, but far below it in productiveness, is Hutti mine. It produced 21,000 ozs. of gold in 1915, but the output fell off and the mine was closed. When they were reopened in 1948, the working had reached a depth of 1,000 feet. This and other abandoned gold workings in the area are receiving the attention of the Government and have found mention in the Third Plan of the Government of India.

West Bengal: In the sands of various streams draining a part of Purulia district, occurrences of flakes and small nuggets of pure gold have been reported by the Geological Survey of India. Some of these occurrences are from the sands of Kansai and Kumari rivers near Ambikanagar, further north near about Mobazaar and near the south of Ambikanagar, within a radius of two miles. "Native" gold is also reported from the Baghmundi thana of Purulia district.

ALLUVIAL GOLD

From references made to vein-gold in the foregoing pages, it can be seen that vein gold occurs in limited areas. The distribution of alluvial gold in India, however, is much wider. Many of the rivers draining the crystalline and metamorphic tracts in India, are reputed to have auriferous sands, but only a few of them are commercially important. Alluvial gold-washing is carried on in the sands and gravels of many of the rivers of Madhya Pradesh and in sections of Indus valley at Ladakh, Baltistan and Gilgit. But none of them is of any appreciable richness.[1]

The present-day production of gold in India has declined to less than 5,000 Kgs. (175,000 Ozs.)

[1] The only instance of successful exploitation of this kind is the dredging of the upper Irrawaddy in Burma for several years; in this way some 5,000 to 6,000 ozs. of gold were won a year; but the returns fell of and the operations were closed down in 1918.

CHAPTER XI

ORES AND METALS (Contd.)

MAGNESIUM

MAGNESIUM DOES not occur in nature in the free state. It commonly occurs in combination as a carbonate, known as magnesite, which is a hard, white, massive mineral occurring as earthy lumps, simulating chalk, generally as a net-work of veins in highly-weathered ultra-basic rocks. Magnesite is believed to be an alteration product of dunites (peridotite) and other basic magnesian rocks. When freshly broken, it is of a dazzling white colour. The oxide, periclase (stable, inert, resistant form of magnesia), which is obtained by heating magnesite at high temperature, has high resistence to heat and is, therefore, used in manufacture of refractory bricks. Magnesite is also used as a bond in abrasives and in the manufacture of some special types of cement (sorel cement) for artificial stone, tiles, fire-proof floorings, etc. and for the extraction of the metal magnesium. Other industrial uses of magnesite are in the manufacture of caustic magnesia, refractory material for use in steel industries and as a source of carbonic gas. The most familiar use of magnesium for the common man is the magnesium wire giving a brilliant glow of incandescent light. Large deposits of magnesite ($MgCO_3$) occur in the district of Salem as veins associated with other magnesian rocks such as dolomite, serpentine, etc. For the occurrence of magnesite in India the following localities are noteworthy:

Madras: One of the largest deposits of magnesite in the world and the largest in India, known so far, occurs near Salem town at the Chalk Hills known locally in Tamil as "Sunnambu Karadu". This magnesite is of a high degree of chemical purity (MgO-46.4%). is easily obtained and, when calcined at a high temperature, yields a material of great refractoriness. Its reserves up to a 100 feet, are of the order of 82.5 million tons. Smaller deposits of similar magnesite occur in Chettipatti, Siranganur, Sirapalli in Salem district

and near Pavitram in Tiruchirapalli district. Magnesite-veins also traverse the basic rocks in the region of Coimbatore. Large refractory works are being set up in the area for manufacturing refractory bricks required by steel plants and other industries.

Mysore: Magnesite veins are found in serpentine rock, derived from ultra-basic rocks in Dod Kanya and Dod Katur in the districts of Hassan and Mysore which are traversed by the same veins as from Madras State stretching upto Coorg on the west coast.

Uttar Pradesh: A large deposit of magnesite occurs in Almora district associated with dolomitic limestone (see Limestone and Dolomite). Important occurrences are in Boragar, Ganai, Phadyori, Rithal, Tachhni, Jajurali, Dewaldhar, Gree China and Dewal Thal. The magnesite is of the crystalline variety, unlike the common chalk-like and earthy types found in southern India.

Reserves of over 20 million tons of magnesite are estimated in the above deposits which are under examination.

Of the total annual output of magnesite in India, a very small amount comes from Uttar Pradesh, while the combined output of Salem and Mysore magnesite workings reach a total of about 262,000 tons, valued at Rs. 48,00,000. The total reserves of this mineral, the principal source of the light metal magnesium, are over 120 million tons (analysing over 96% of magnesium carbonate, 46.4% M_gO) at an average depth of 100 feet. Dolomite (magnesium limestone) also occurs in extensive deposits in many parts of the Himalayas and South India, thus adding to the potential reserves of magnesium metal, useful in manufacturing aluminium-magnesium and other light-metal alloys. Very little magnesite is used in India for the extraction of metallic magnesium. The quantity mined is usually employed in the making of caustic magnesia, sorel cement, magnesia bricks and other refractories; a considerable part of the annual output is exported. Research on the preparation of metallic magnesium, light-metal alloys and magnesium-aluminium alloys is actively being pursued by the Council of Scientific and Industrial Research.

MANGANESE

Manganese is distributed[1], in greater or less proportion, in almost all the geological systems of India, from the Archaean to the Pleistocene, but the formation which may be regarded as the principal carrier of these deposits is the Dharwar. The richly manganiferous facies of this system—the Gondite and Kodurite series—contain enormous aggregates of manganese-ores such as psilomelane and braunite, pyrolusite, hollandite, etc. Of these the first two form nearly 90% of the ore-masses. The geological relations of the ore-bodies contained in these series and their original constitution have been well studied in India. Besides the Dharwar system, workable manganese deposits are contained in the laterite-like rock of the various parts of the Peninsula, where the ordinary Dharwar rocks have been metasomatically replaced by underground water containing manganese solutions. According to the mode of origin, the two first-named occurrences belong to the *syngenetic* type of ore-bodies, *i.e.*, those which were formed contemporaneously with the enclosing rock, while the last belong to the *epigenetic* class of ores, *i.e.*, those formed by a process of concentration at a later date. Manganese is chiefly used for making special steels and in the manufacture of ferro-manganese and spiegeleisen both of which are alloys of manganese and iron. Manganese is employed in several chemical industries as an oxidiser, in the manufacture of bleaching powder, in the preparation of disinfectants, gases, colouring material for glass, pottery paints and other chemicals. It is also used with other metals in the manufacture of alloys. The black powder contained in the familiar electric torch-light cells is mostly manganese-dioxide, which occurs in nature as the minerals pyrolusite and psilomelane. The pink mineral rhodonite, which is the silicate of manganese, is sometimes cut for gems on account of its colour and appearance. The following are the centres of

[1] A voluminous memoir on the *Manganese-Ore Deposits of India* by Sir L.L. Fermor, published by the Geological Survey of India, contains valuable information on the mineralogy, economics and the geological relations of the manganese of India.

manganese mining—rather quarrying, the method of extraction resorted to so far being one of open quarrying from the hill-sides:

Andhra Pradesh: The chief ores of manganese here are psilomelane, pyrolusite, braunite and mangan-magnetite. Srikakulam district has the distinction of being the earliest producer (1892) of manganese-ore in India. The ore is generally low to medium in grade and is high in phosphorus. Deposits are found in Kodur Garividi, Garbham, Perapi, Devada, Sadanandapuram and a number of other localities in Srikakulam and Vishakapatnam districts. The output from those mines from 1892 up to 1954 has exceeded 2.3 million tons. The estimated reserves down to 100 feet depth are 5,00,000 tons with high phosphorus content and 20 to 30 per cent of manganese.

Bihar: Manganese-ore deposits occur over a belt extending southward from Gua to Limtu and beyond into Orissa, between Chaibasa and Jamda and between Jamda and Noamundi. The extent and resources of ores in these deposits are yet to be proved. About a third of the deposits contain more than 40% manganese.

Gujarat: Deposits of manganese-ore occur in Panch Mahals and Baroda districts. The deposits of the former occur along a belt extending from Bapotia to Pani, a distance of about sixteen miles. Small deposits of manganese-ore occur near Jothwad, Malbar, Bhaber, Van, Gandhra and a few other places in Panch Mahal district. First-grade ore is available from this district.

Madhya Pradesh: The manganese-ore occurrences of Balaghat and Chhindwara districts constitute one of the most important sources of manganese-ore in India. The Balaghat deposit is $\frac{1}{4}$ mile long, while another band, running through Jamarpani, Tirodi and Ponia in Balaghat, is exposed more or less continuously for 6 mile. The deposits, particularly at Tirodi and Balaghat and the ore at Kachi-Dhana in Chhindwara district, are large and of good quality. Small deposits also occur in Bilaspur and Jabalpur districts. In India, ores containing over 48% of manganese are classed as first grade, those with 45 to 48 per cent contents are considered second grade and those with less than 45% as third grade.

The Madhya Pradesh State yields the major part of the total Indian output of good quality ores.

Maharashtra: Some of the best deposits occur in Nagpur, Bhandara and Ratnagiri districts; those of the first two occur in bands. Float-ores, or boulder deposits, are also found here. In Nagpur district the ore occurs over a wide area. The quantity estimated to be present is about three million tons. In Bhandara district, the major deposits occur near Dongri Buzurg and Chikhla. Minor deposits are found scattered in 13 localities. The total reserves of the major deposits are estimated to be about 4.5 million tons. In Ratnagiri district manganese-ore occurrences are noticed in Sawantwadi *taluk* as irregular boulders in laterite. The ore, in general, is of low grade and occurs near Banda, Degve, Adali, Kalne, Phondye Dingue and Galel. These deposits not being very promising, their workability depends on the market demand.

Mysore: Most of the manganese deposits in the State are confined to Shimoga, Chitradurga and Tumkur districts. In Shimoga district, some of the most important ore-bodies are situated along the crest of a ridge and to the north of Kumsi. Ferruginous ores have been found along the ridge of Adgadde and Hemmakki. Smaller deposits are found distributed in about 7 localities. In Chitradurga district, deposits have been found at many places but the ores are mostly poor and highly ferruginous. In the Sandur hill range of Bellary district, the lateritoid deposits (high iron and low manganese) have been worked for the most part. It is estimated that there is still about 800,000 tons of ore available.

Orissa: Deposits occur in three widely separated areas: (1) Keonjhar-Bonai belt; (2) Koraput-Kalahandi belt and Patna district; (3) Gangapur area, Sundargarh district. The total known reserves of all grades are nearly 22.2 million tons. The low-phosphorus manganese-ore deposits of Keonjhar-Bonai are next in importance only to the famous deposits of Madhya Pradesh. These deposits are scattered in a triangular area, covering Barbil, Dhubna and Bhutura, to the south-east of the main iron-ore range. Proved reserves of all grades near the existing quarries are about 4.5 million tons and the probable reserves are near 20

million tons, of which 30% is estimated to contain over 40% manganese. The ores vary widely even in a single deposit; some deposits may yield small amounts of chemical and battery-grade ore. The deposits of Koraput-Kalahandi area are chiefly confined to a 20 mile long belt from Koraput district to Kalahandi district. Of the several deposits in this belt those at Kutingi are said to be of excellent quality. Proved total reserves in this area are estimated at 1 million tons. In Bolangir district, the ore deposits are scattered in an area 15 miles long and 6 miles wide, about 12 miles west-north-west of Bolangir. Proved total reserves are about 0.15 million tons. In the Gangapur area of Sundargarh district, ore-deposits are known to occur at several places over a distance of 40 miles but at present there is no production from these deposits.

Rajasthan: Important deposits occur in Banswara and Udaipur districts. About 250,000 tons of ore with an average of 45 to 50 percent of manganese is estimated within 30 to 50 feet from surface in Banswara district. Some ore is recorded from Udaipur district. Minor occurrences are also known in Ajmer district, in Alwar and in Bharatpur district. Ores which contain 40 to 60 percent of manganese are common and are classed as *manganese-ores*. There also exist ores with an admixture of iron from 10 to 30 percent; these are designated *ferruginous managanese-ores* while those which have a still greater proportion of iron in them are known as *manganiferous iron-ores*:

Production of Manganese in India

With her extensive deposits in the above-mentioned regions, India has occupied, for over 30 years, either the first or the second place amongst the world suppliers of manganese metal. It is now estimated that the deposits in the main belt of Nagpur, Bhandara and Balaghat in Madhya Pradesh and Maharashtra States alone contain reserves, up to a depth of 100 feet, of which 55 million tons are of shipping-grade ore, *i.e.*, with 45% manganese and above. 12 million tons of ore are estimated to be available from the deposits in other States. With the exception of Russia and Brazil, India is the largest producer of manganese in the world. Within the

last 40 years, particularly between the two World Wars, the annual export of high-grade manganese-ores has risen from a few thousand tons to touch the million-ton mark. The output has, in recent years, however, fluctuated considerably. The major part of this output is exported in the ore condition, a comparatively small part of it being treated in the country for the production of the metal, or for its manufacture into ferro-manganese, the principal alloy of manganese and iron. Production of ferro-manganese has lately risen to 75,000 tons per annum.

Economics

The minimum reserves of the richer grade ores (chemical grade with Mn$>$ 70%, and first-grade with Mn$>$ 48%) are not large, computed at only 15-20 million tons. Reserves of second-grade ore (Mn 40-30%) are several times this magnitude. Beneficiation of Mn-content of a large proportion of leaner ore-bodies and increasing their commercial value is now being carried out. The unlimited export of manganese-ores in the raw state has now been controlled by Government, tighter restrictions being put on the export of the superior-quality ores. Factory-scale experiments on the manufacture of ferro-manganese are now receiving serious attention. With the finds of low-phosphorus ores in Sandur (Madras State) and Balaghat (M.P.) and the availability of non-phosphatic coke from Giridih (Bihar State), Pilot-plant trials for conversion of a fair percentage of manganese-ores to ferro-manganese is a welcome development in the metallurgical industry of India.

Strontium

A fairly large deposit of the mineral celestite (96% $SrSO_4$) has been found in Tiruchirapalli district, estimated to contain half a million to a million tons of fairly pure grade material within 100 feet of the surface. The mineral has not found industrial employment in India, *e.g.*, paints, chemicals, and drug manufacture, only a small proportion being used in pyrotechnics.

Tin

With the exception of a few isolated occurrences of cassiterite (oxide of tin) crystals in Palanpur and its occurrence *in situ* in small deposits in the gneissic rocks of Hazaribagh, no commercially workable ore of tin is found in India. India's requirement of tin, around 5,000 tons annually, is met wholly by imports, valued at rupees 5.6 crores.

In the neighbouring region of Burma, from which India probably derived its supplies of tin in the past, there occur deposits of tin-ore of workable proportions (the Mergui and Tavoy districts of Lower Burma) which have supplied a large quantity of tin from a remote antiquity. The most important tin-ore is cassiterite, occurring in quartz-veins and pegmatites, associated with wolfram in granitic intrusions traversing the Mergui series. But the greater proportion of tin-ore is obtained, not from the deposits *in situ*, but from the washing of river-gravels (*stream-tin* or *tin-stone*) and from dredging the river-beds of the tin-bearing areas, where the ore is collected by a process of natural concentration by running water.

Titanium (Ilmenite)

Titanium occurs in its two compounds, ilmenite (FeO, TiO_2) and rutile (TiO_2), the former of which is of wide distribution in the charnockite and other gneisses of the Peninsula, Bihar and Rajputana. It occurs extensively in the form of alluvial deposit on the beaches of Kerala and Madras coasts as black, heavy sand, along with monazite, zircon, garnet and other heavy minerals. Here the volume and degree of concentration of heavy mineral grains are on a scale unknown elsewhere. The largest deposits are on the Kerala beaches on a 100-mile stretch between Cape Comorin and Kayankulam. Small patches of the sand concentrates occur at Ratnagiri and further north on the Malabar coast and also on the East Coast at Tuticorin, Vishakapatnam and Ganjam. The ilmenite (including arizonite) is rich in TiO_2, the average content of titania ranging between 54 to 62 percent. The total reserves of ilmenite, extractable from the beach and placer sands by magnetic separation is estimated at over 150 million tons.

Associated with ilmenite sands are rutile, zircon, monazite, columbite, tantalite, garnet and sillimanite. Monazite forms roughly 1 to 3 percent of the beach-sand grains.

Titanium also occurs as titaniferous magnetite in large masses in Singhbhum and Mayurbhanj and, in some quantity, in pegmatites at several localities. Rutile, mainly TiO_2, is obtained, to the extent of 1000 to 2000 tons annually, in the magnetic separation of ilmenite from the raw beach sands. The annual export of ilmenite from India was of the order of 100,000—200,000 of tons. Local utilisation of ilmenite for the manufacture of titanium oxide, so far not undertaken, is now projected on a small scale at Kerala. The chief use of ilmenite is in the manufacture of white paints, lacquers and varnishes, the capacity and covering power of titanium oxide being very high. Titanium is also used in the manufacture of better grades of paper, as a white colouring for rubber compositions, printing inks, plastic articles, soaps and cosmetics. Ilmenite is now utilised for manufacture of titanium metal which possesses some remarkable properties and is regarded as the metal of the future, especially in aircraft and chemical engineering industries. Prior to 1950, about 75% of world's requirements in titanium, ranging between 200,000 to 300,000 tons per annum, were supplied from the ilmenite beach sands of Kerala. This export trade has fallen since 1963.

DISTRIBUTION

Bihar: A large quantity of ilmenite sand, along with monazite and zircon, occurs as alluvial placer deposits on parts of the Hazaribagh plateau, Bihar, under the soil-cap.

Gujarat: Ilmenite sand deposits occur along the coast in the districts of Surat and Jamnagar. Pockets of ilmenite sands also occur in the beach sands near Bulsar. Not being extensive, these have limited commercial significance.

Kerala: The largest and richest deposits of ilmenite occur, along with monazite and zircon, in the beach sands and dunes occurring between Quilon and Kayankulam where the concentration is reported to be between 38% and 65%. The reserves

are around 100 million tons.

Maharashtra: Fine black sand along the coastal strip in Ratnagiri district contains ilmenite. The strip extends from Purnagadh to Vengurla. The important deposits are near Rajwada, Bhatia, Ratnagiri port, Purnagadh Goankhadi and Malgund. The titanium percentage varies from 28 to 43.

Orissa: The sands of the Wheeler Islands, off the coast of Chandbali, in Balasore district, are rich in ilmenite, magnetite, zircon, rutile and minor amounts of monazite, which is a source of thorium. The concentration of heavy minerals in the sand here is barely 4%.

As seen above, the beach sands of Kerala constitute the most prolific source of this mineral. In 1957, about 296,221 tons of ilmenite were produced in the country, the highest figure of production, the major part of which was exported. Since then, the foreign demand for ilmenite has fallen sharply due to competition from other producing countries.

Tungsten (Wolfram)

Tungsten metal possesses several valuable properties which give to it its great industrial and strategic defence utility. Among these the most important is the property of "self-hardening" which it imparts to steel when added to the latter. Over 95% of the wolfram, the chief ore, is absorbed by the steel industry. All high-speed steel-cutting tools have to contain a certain proportion of tungsten. Tungsten steel is largely used in the manufacture of munitions, armour plates, heavy guns, etc. and enables them to stand the heavy charge of modern explosives. In World War II Indian Ordnance Factories produced some tungsten-steel along with other alloys for munitions use. Tungsten, by repeated heating, acquires the property of great ductility. Hence, wires of extreme fineness and great strength suitable for electric lamps, the fine glowing wires of filament not melting even at white heat within the light bulbs are familiar sights. Tungsten compounds are also used in paints, ceramics and textiles. The only Indian occurrence of wolfram, the chief ore of tungsten, is near Degana in Jodhpur district

of Rajasthan, with an average wolfram content around 0.65%. This and some sporadic occurrences of wolframite (associated with scheelite) in Bankura district in West Bengal and of scheelite, calcium tungstate, reported from Andhra Pradesh, are not sufficient to support remunerative mining in normal times. The Rajasthan deposits yielded, during World War II, a couple of hundred tons of wolfram. Only 29 cwts. of wolfram were produced in 1957 from this source.

[THORIUM—URANIUM *on pages 183-4*]

VANADIUM

Vanadium-bearing iron-ore, containing V_2O_5, in quantity varying from 1 to 4 percent, has been discovered in deposits of considerable size, but with a fitful distribution of the vanadium content, in Singhbhum and Mayurbhanj areas of Bihar and Orissa. Its exact paragenesis and relation with the country-rocks are not yet known, but the ore occurs in association with basic igneous intrusions in Dharwar rocks. The vanadiferous ores are titanium-bearing iron oxides (V_2O_5—0.8 to 3 percent), the deposits being estimated to be 25 million tons. Radiometric analysis of vanadium-ore concentrates, obtained from the dressing of vanadiferous ores, reveals the presence of mintue amounts of uranium. Vanadium is a white, silvery metal which does not occur free in nature. It is mostly used in the manufacture of steel alloys for special purposes such as high-speed cutting steels, die-steels, etc. Vanadium salts are used for various processes connected with chemical manufacture, ceramic ware, etc. Vanadium-bearing magnetite occurs in Singhbhum area (Bihar) and Mayurbhanj area (Orissa); a vanadiferous mica has been reported from Madhya Pradesh. The ash of the lignite in Madras is also reported to contain appreciable amounts of vanadium. In Bihar, vanadium, associated with magnetic iron-ores, occurs in Dublabera and adjoining areas in Singhbhum district. About 2.5 million tons of vanadium-ore, assaying 9.54 to 1.98 percent of vanadia, are estimated to occur in Dablabera. The total reserves of vanadiferous iron-ores are estimated

at some 3 to 5 million tons. These ores contain enough of vanadium for their conversion to vanadium-steel and other alloys. No industry using vanadium, however, exists in India and no actual production is reported at present.

ZINC

The commonest reference made to zinc is in connection with the corrugated roofing-sheets made of iron and coated with zinc to prevent rusting. When zinc is alloyed with copper, the familiar alloy brass is obtained. Zinc is also used in the manufacture of collapsible tubes containing drugs, pastes and the like. Zinc oxide and zinc sulphide are used as pigments; while zinc chloride is used in soldering and as a coating in preventing decay in wood. Zinc does not occur free in nature; it occurs commonly as sulphide mineral sphalerite or zinc-blende. Sphalerite is commonly associated with galena, the ore of lead.

Jammu and Kashmir: A workable deposit of zinc-blende of considerable purity, occurring in lenticular veins and lodes, has been discovered in a Permo-Carboniferous limestone in the Riasi district of Kashmir in association with Tertiary rocks. The veins sometimes swell to nests of 500 cubic feet, while some thousand tons of detrital float-ore occur in the vicinity. The presence of sphalerite (zinc sulphide) in the limestone of Darabi area in Udhampur district is also an indication of the possibility of small reserves of zinc-ores being found in the area.

Rajasthan: In recent years the Geological Survey of India has conducted considerable work on the zinc-lead deposits of Zawar in Udaipur district, an area which produced considerable amount of metallic zinc a century or two ago. The re-opened Zawar mines, which show occurrences of zinc-lodes (blende) in association with lead ores, galena, are, so far, the only source of workable zinc in the country. The total reserves of good-grade ore have been estimated at 734,000 tons containing, on an average, 7.16% lead and 7.49% zinc. This figure does not include two million tons of medium-grade ore containing 1.9% lead and 3.8% zinc and eight million tons of low-grade ore containing an average of 3 to

4% compound metal. About 10,500 tons of zinc concentrates are produced at Zawar annually, but no smelting is carried out yet at the site.

With regard to the extensive mineralisation of this area, it is estimated that at Mochia Magra, where the operating mines are located, the indicated and inferred reserves of ore amount to about 10 million tons of all grades ranging from 3 to 12.5 percent combined metals, the ore being generally richer in zinc than in lead. The ore is concentrated in flotation mills near the mines. The lead concentrates are further treated at Tundoo Smelting Works in Bihar for the recovery of lead and silver, while the zinc concentrates are shipped overseas for smelting to Japan.

Lead-ore is also reported to occur in Dungarpur, Banswara, Sawai Madhopur and in Alwar districts. The total production of zinc and lead concentrates in 1964 was 10.391 and 5,341 metric tons respectively. The lead-concentrates in the same year yielded 4,038 kilograms of silver.

Minor Occurrences

West Bengal: Small pockets of argentiferous galena, cerussite, sphalerite and limonite occur in the dolomite bands in Buxa Duars area of Jalpaiguri district. Lead-ores occur also in a number of other places in Darjeeling district and western Duars area. Minor deposits of lead-zinc have been located at Almora, Tehri Garhwal, and Bhotang (Sikkim). The main ore bodies are sphalerite, calamine and hemimorphite, in association with lead compounds and minor amounts of cadmium and silver. In the new smelter plants that are being projected for zinc, the recovery of these, along with sulphur (hitherto lost in the treatment of sulphidic ores in India), for manufacture of sulphuric acid, will be carried out. The annual consumption of zinc today in India is over 80,000 tons.

CHAPTER XII

PRECIOUS AND SEMI-PRECIOUS STONES

DIAMONDS

As A highly prized gem-stone diamond has been cherished throughout the ages. Because of its brilliant, adamantine lustre, transparency and hardness, diamond has been a highly valued gem. Black diamonds, low-grade, flawed stones, "bortt," and "carbonado," are of industrial value and used extensively for polishing the surface of metals, minerals, etc. and in gem-cutting. Its most important industrial use is in cutting-edges of drills which are indispensable in modern exploration and mining of minerals. Like graphite, diamond consists entirely of carbon atoms: it is the difference in the arrangement of the atoms that gives the two minerals their entirely different properties. In ancient times, India had acquired great fame as a source of diamonds, all the celebrated stones of antiquity being the produce of its mines, but the reputation has died out since the discovery of the diamond mines of Brazil and Transvaal; at the present time the production has fallen to a few stones annually of indifferent value. Even so late as the times of the Emperor Akbar, diamond-mining was a flourishing industry, because the field of Panna alone is stated to have fetched to his government an annual royalty of 12 lakhs of rupees. The localities noted in history as the chief diamond centres were Bundelkhand (for "Panna Diamonds"); districts of Kurnool, Cuddapah, Bellary, etc. in Madras State (containing the "Golconda diamonds"); and some localities of Central India such as Sambalpur, Chanda, etc. The diamondiferous strata in all cases belong to the Vindhyan system of deposits. A certain proportion of diamonds was also obtained from the surface-diggings and alluvial-gravels of the rivers of these districts. Two diamond-bearing horizons occur among the Upper Vindhyan rocks of central India: one of these (Panna region) is a thin conglomerate-band separating the Kaimur sandstone from the Rewah series. The diamonds are not indigenous

to the Vindhyan rocks but have been assembled as rolied pebbles, like the other pebbles of those conglomerates, all derived from the older rocks. The original matrix of the gem, from which it separated out by crystallisation, probably lies in the dykes of basic volcanic rocks associated with the Bijawar series, some of which have been mapped recently. The dykes of basic lava that have penetrated the formation are supposed to be the parent-rock of the diamonds of India. The celebrated "Golconda" diamonds were mostly derived from a conglomerate mainly composed of the rolled pebbles of these dykes. Small diamonds are found in the matrix of this rock, which may be found to correspond to the "diamond pipes" of Kimberley, the prolific source of South African diamonds. In Andhra Pradesh, many historical diamonds have been recovered from the Krishna basin. The "Koh-i-noor", 186 carats, and the "Pitt", 410 carats, are among the most famous diamonds produced by India. The value of the "Pitt", re-cut to 136¾ carats, is estimated at £480,000. Some of the important ancient workings are seen in Sub-Recent alluvium around small places in Krishna district. Diamond also occurs in Banganapalle in Kurnool district. Of the other diamond localities, Anantpur district, Guntur district and Bollaram deserve mention. Even at present, after the rains, stray pieces of diamond are collected by villagers in the above districts and the Banganapalle areas.

In Madhya Pradesh, diamonds occur in the conglomerates and the associated alluvial deposits in Panna district. Here, the principal diamondiferous stratum is a thin layer of conglomerate locally known as "Mudda", in the matrix of which diamonds occur. They are also found in the neighbouring detritus formed by the disintegration of Vindhyan rocks. Diamond also occurs *in situ* in the serpentine rocks at Majhgawan mines, in Shahidan area and in Panna district. The occurrence is similar to that of Kimberley in South Africa. A pipe of ultra-basic rock, resembling the kimberlite of South African diamond fields, has been lately located in one of the Panna fields. Mining of diamonds from this pipe-rock has given encouraging results, though the output is yet quite small. Amongst the other famous diamonds obtained in the past from the

above-noted localities are the "Great Mogul", 280 carats; the "Nizam", 277 carats; the "Orloff" 193 carats and the blue "Hope".

At present very few stones of gem quality as well as industrial diamonds are produced; the annual returns show barely 2000 carats of the former type, in small stones, per year. It does not appear, however, that the Indian diamond deposits are exhausted. Intensive prospecting and mining by modern methods, in place of the crude and primitive diggings of old, are being employed to revive the alluvial and placer mining in Panna, Kurnool, Bellary and other places in Central India. Amongst the more recent yields may be noted the "Vijai", the diamond found in 1961 and auctioned for over Rs. 5 lacs and an equally precious diamond weighing 16.9 carats struck at the Panna diamond mines, about 45 miles from Satna in 1964.

Rubies and Sapphires

Red-coloured rubies and blue-coloured sapphires, crystallised and transparent, prized as gems from times immemorial, are varieties of corundum (see section on Economic Minerals). Rubies of deep carmine-red colour, the colour of "pigeon's blood" and perfect lustre are often of greater value than diamonds.[1] The matrix of the ruby is a crystalline limestone—ruby limestone—associated with and forming an integral part of the surrounding gneisses and schists. The rubies are found *in situ* in the limestone along with a number of other secondary minerals occurring in it. Some stones are also obtained from the hill-wash and alluvial detritus. In Kashmir region, pale rubies are found in some kaolinised pegmatites at an altitude of 15,000 to 17,000 feet. The

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[1] *Burma*: Rubies are mined in the Mogok district (Ruby Mines district) of Upper Burma, north of Mandalay, which has been a celebrated locality of this gem for a long time. The best rubies of the world came from this district from an area covering some 25 to 30 sq. miles of which Mogok is the centre.

The output of the Burma ruby mines amounted, some years ago, to over £95,000 annually. (One ruby from the Mogok mines, 38½ carats in weight, was sold for £20,000 in London in 1875). The output has, however, declined of late years. The average annual royalty of Rs. 1,70,000 indicates the state of the industry before II World War.

main source of sapphires in India has been Kashmir ever since the gem was first found there in 1882. It occurs there as an original constituent of a fine-grained, highly felspathic gneiss in the Padar area in Kishtwar district at a considerable elevation. Transparent, crystallised corundum (gem-variety) also occurs in some kaolinised pegmatite cutting actinolite-schist lenticles in Salkhala marble at an altitude of 15,000 to 20,000 feet. (Associated minerals in the pegmatite are prehnite, tourmaline, beryl, spodumene and lazulite.) Sapphires were also obtained from the talus debris at the foot of the hill-slopes. Stones of perfect lustre and high degree of purity have been obtained from this locality in the earlier years, some of the crystals being upto 5 inches in length; but the larger and more perfect crystals, of value as gems, appear to have been exhausted since 1908. Later discovery, however, by the Mineral Survey of Kashmir, has revealed a large quantity of crystallised, transparent corundum. The bulk of the output from the mines is now confined to what are called "rock-sapphires", valueless for gems and of use as abrasives, watch-jewels, etc.[1]

Emeralds and Aquamarines

Beryl (see Section on Metals and Ores), when transparent and of perfect colour and lustre, is a highly valued gem. Its colour varies much from colourless to shades of green, blue or even yellow. The much-prized green variety is the emerald, while the blue is distinguished as *aquamarine*. Emeralds are rare, the only locality

[1] *Ceylon*: Sapphires of good water and colour, and to a less extent, rubies of indifferent colour, are the more prized stones found in the gem-sands and gravels in Ratnapura district, occurring within a hundred feet from the surface, often less in late-Tertiary and post-Tertiary deposits. These alluvial gem-bearing gravels of Ceylon, which have supported precious and semi-precious stone-mining centres for centuries, without apparent exhaustion, must be counted amongst the most prolific gem-fields of the world. The other more common gem-stones found in these beds are topaz, spinel, zircon (hyacinth and jargon), aquamarine, chrysoberyl (alexandrite and cat's eye), tourmalines (rubellite and indicolite), garnets (pyrope and almandine), moon-stone, amazon-stone (the gem varieties of felspar), amethyst and rock-crystal.

in India is in Mewar, where crystals of exquisite colour and water were discovered in 1943 in a band of biotite-gneiss in hornblende-schists. This locality has yielded about one million rupees worth of first-quality emeralds, the crystals varying from ½ to 4 inches in length. Aquamarines suitable for use as gems are obtained from pegmatite-veins crossing the Archaean gneiss at some places in Bihar and Nellore. Good aquamarines also occur in Coimbatore district and in Mewar, Ajmer and Kishangarh (Rajasthan). Stones of considerable value were once obtained from these localities. A highly productive locality for aquamarines has been discovered in the Shigar valley of Skardu (Kashmir) whence crystals of considerable size and purity are recovered. The gem occurs in coarse pegmatite veins traversing biotite-gneiss. Common beryl occurs in very large crystals, sometimes a foot in length, in the granite-pegmatite of many parts of India, but only rarely they include some transparent fragments of required purity. In 1957, the production of emerald was 338,000 carats.

JADEITE

Jade is a highly-valued ornamental stone on account of its great toughness, colour and the high lustrous polish it takes. A large number of mineral compounds pass under the name of *jade*, but the true mineral, also named *nephrite*, occurrence of which is so much sought after, is a comparatively rare substance not known in India.[1] True jade is a product of China; it also come into India from the Karakash valley of South Turkestan.

SANG-E-YESHM

Regarded as jade in Punjab, this is only a variety of serpentine. It differs from the genuine mineral in all its characteristics, being not so tough, much softer and incapable of receiving the exquisite polish of jade.

[1] A mineral greatly similar to it in many of its qualities and known as *jadeite* is largely quarried in Burma.

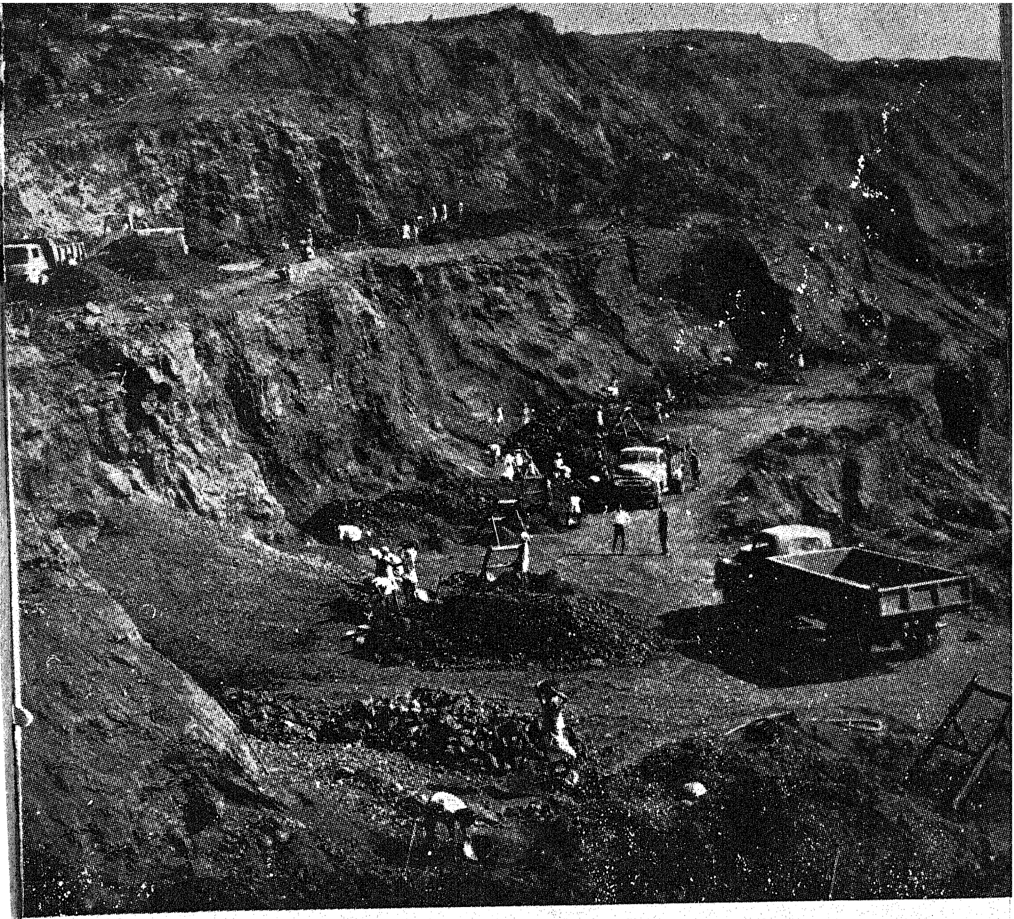


Fig. 6. OPEN-CAST WORKING OF IRON-ORE MINE, GOA

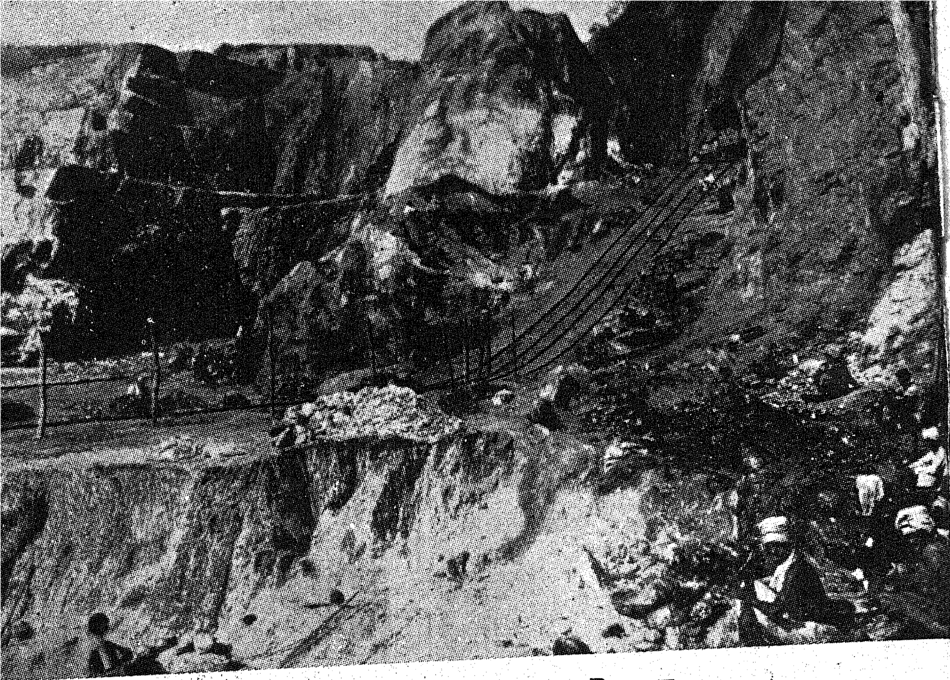
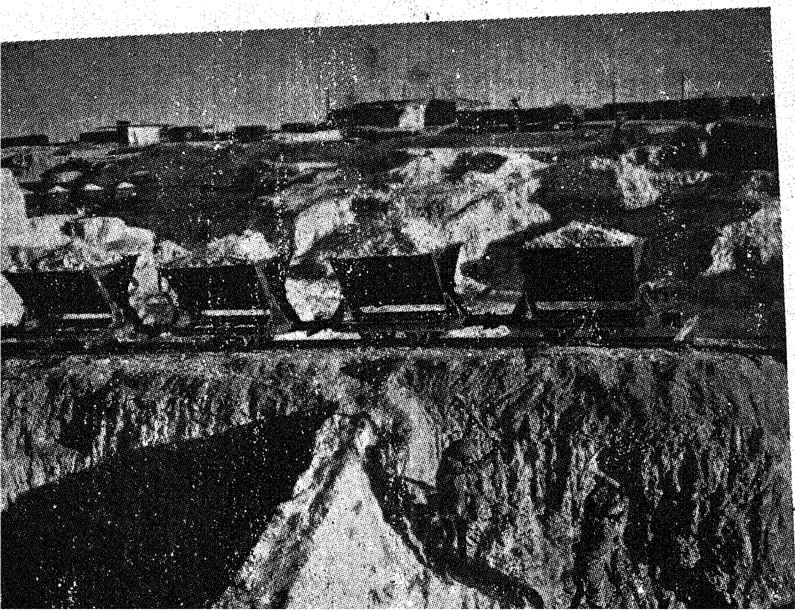


Fig. 7. MANGANESE-ORE MINE, BHANDARA DISTRICT

Fig. 8. EXCAVATING GYPSUM AT JAMSAR, BIKANER



Chrysoberyl

Chrysoberyl, a compound of beryllium and aluminium oxides, is a stone of different composition from beryl. It is green in colour. A few good stones in the form of platy crystals of greenish-white to olive, of tabular habit are obtained from pegmatite veins in Kishangarh in Rajasthan, which also yield mica and aquamarines. They are found in some felspar-veins in the nepheline-syenites of Coimbatore and Kerala regions. Usually they are too much flawed and cracked to be suitable for cutting as gems. Chrysoberyl crystals, when possessing a chatoyant lustre are known as "cat's eyes".[1]

Garnet—(See Section on Economic Minerals)

Transparent variety of garnet is used as semi-precious stone since it possesses a great many requisites of a gem-stone—a high refractive index and lustre, great hardness, pleasing colour, transparency, etc.—and would be appreciated as such, were it but put on the market in restricted quantities. Garnets are most abundant in the metamorphosed rocks of Rajasthan, especially in the mica-schists where large transparent crystals are frequently found. Quantities of garnets are exported to foreign countries for use in cheap jewellery. The variety used for this purpose is almandine, of crimson to red and violet colours. Its occurrence is cofined mainly to parts of Andhra Pradesh, Madras, Mysore and Rajasthan. Crystals of large size, derived from Purana mica-schist, are worked at Jaipur, Delhi and Kishangarh where they are cut into various shapes for gems. Those of Kishangarh are considered to be the finest in India and support a regular industry annually of about a lakh of rupees.

Spinel

Spinel, when of sufficient transparency and good colour, is used in jewellery; it constitutes the gem ballas-ruby when of rose-

[1] *Alexandrite*, is its deep emerald-green variety found in Ceylon; it has exquisite colour and pleochroism, showing green by reflected light and deep red by transmitted light.

red colour and spinel-ruby when of a deeper red. Rubicelli is the name given to an orange-red variety. Spinel rubies occur in the Burmese area associated with true rubies. They also occur in Ceylon in the well-known gem-sands along with many other semi-precious and ornamental stones.

Zircon

Zircon has an adamantine lustre and high dispersion power, its refractive index being very high, 1.92—1.98. Zircons occur in the alluvial soils in Ranchi and Hazaribagh districts of Bihar, Uttar Pradesh and various other parts of India; but none of them are flawless or have the degree of transparency required in a gem. *Hyacinth* (the transparent red variety) is found at Kedar Nath on the upper Ganga.

Tourmaline

Pellucid and beautifully coloured varieties of tourmaline, red, green or blue are worked as gems. The green variety, known as *indicolite*, occurs in Hazaribagh (Bihar) and in Padar district of Kashmir, where some transparent crystals, *rubellite*, the red variety, are also found. This variety of tourmaline possesses greater transparency, but is much fissured.

Other Gem-stones of India

Besides the above-named varieties, other crystallised minerals, when of fine colour and attractive appearance and possessing the other qualities of gems, *e.g.*, hardness, transparency, lustre are cut for ornamental purposes. Among such minerals are the kyanites (or cyanites) found at Narnaul in the Patiala area of Punjab, rhodonite (pink manganese silicate) of some localities of Madhya Pradesh, apatite (a sea-green variety) met with in Rajasthan. Amazone-stone is a blue-green ornamental variety of microline felspar, occurring in Kashmir and elsewhere. Gem-cutting is a regular industry in places like Delhi and Jaipur. Among other crystallised minerals are the pleochroic mineral iolite or cordierite and moon-stone—a pearly, opalescent orthoclase—met with in

Ceylon. Turquoise, opaque, of fine blue colour, usually uncut, which is commonly sold in the bazars of Kashmir and Darjeeling, is a product of Iran or Tibet, occurring in seams or patches in trachytic rocks.

AGATES

These semi-precious stones are obtained from the amygdaloidal basalts of the Deccan, where various kinds of chalcedonic silica have filled, by infiltration, the steam-holes or cavities of the lavas. The agates are mainly composed of chalcedonic silica, originally deposited in geodes or cavities in basaltic lavas which cover extensive parts of Gujarat and Maharashtra. Other forms of chalcedanic silica, carnelian, heliotrope, blood-stone, onyx, jasper, common opal, etc. are known under the general name of *akik* (agate) in India. In Mysore State the jasper variety of *akik* is found near Thimmapapagarh in Sandur *taluk* of Bellary district. With its multi-coloured bands agate is a popular medium for ornamental purposes, such as brooches, rings, snuff-boxes, etc. and for making mortars used in science laboratories and as an abrasive. Agate wedges, pivots and bearings of scientific instruments are now cut in India. In Gujarat State, the chief place which supplies the raw *akik* is Ratanpur in Rajpipla zone, where rolled pebbles of amygdaloids are contained in a Tertiary conglomerate. On mining, the stones are first baked in earthen pots; this process intensifies the colouring of the bands in the agates. The cutting and polishing is done by the lapidaries of Cambay, who fashion out of them (after a most wasteful process of chipping) a number of beautiful but small articles and ornaments. The annual output at Ratnapur is about a hundred tons. Cambay used to be a large market of Indian agates in Medieval times for different parts of the world.

In Madhya Pradesh, the geodes of the Deccan Traps (basalts) contain varieties of agate, carnelian, opal, onyx, jasper. These minerals are commonly found in streams draining the Deccan Trap area and are abundant in the bed of the Narbada river.

Rock Crystal

Rock crystal, or crystallised transparent quartz, is cut for ornamental objects such as cheap jewels (*vallum* diamonds), cups, handles, etc. The chief places are Tanjore, Kalabagh, Kashmir whence crystalline quartz of requisite purity and transparency is obtained.

Amethyst and Rose-quartz

These purple and pink-coloured varieties of rock-crystals are cut as ornamental stones and gem-stones. Amethyst occurs in some geodes in the Deccan Trap, filling up lava cavities near Jabalpur and in Bashar area (Punjab). Rose quartz occurs in Chhindwara and Warangal area in Madhya Pradesh. Flawless, water-clear, unstained, right and left handed quartz crystals are in demand, because of their piezo-electric property, by the radar and electronic industries.

Aventurine

Aventurine is a kind of feldspar, spangled with minute crystals and plates of haematite, ilmenite, limonite, etc. From ancient times it has been prized as a gem-stones. A green and glistening variety of aventurine is reported to occur in Bellary district of Mysore State. It is found in a ridge near Metri. Its bluish-green variety occurs near Belavadi in Hassan district and a banded green variety near Sindagere about 3 miles N.W. of Belavadi.

Lapidary Industry

Besides the centres mentioned above, there is a lapidary industry at Jabalpur which utilises these semi-precious stones and produces polished stones. In Banda, Uttar Pradesh, also the industry once flourished. Much scope exists in India for systematic development of gem industry; the use of semi-precious stones, spinel, topaz, garnet and rock-sapphire for the manufacture of watch-jewels and pivot-bearings for scientific instruments is receiving attention.

CHAPTER XIII

ECONOMIC MINERALS AND MINERAL PRODUCTS

HERE WE shall consider the remaining economic mineral products, mostly non-metallic minerals of direct utility or of application in the various modern industries and crafts. They include salts and saline substances, refractories, fluxes, raw materials for a number of manufactures and substances of economic value such as abrasives, soil-fertilisers, the rare minerals, etc. With regard to their geological occurrence, some are found as constituents, original or secondary, of the igneous rocks; some as beds or lenticles among the stratified rocks, formed by chemical agencies; while others occur as vein-stones or gangue-materials occurring in association with mineral-veins or lodes or filling up pockets or cavities in the rocks. The more important of these products are described below:

ALKALINE SALTS

Large amounts of alkaline sodium salts—carbonate, bicarbonate and sulphate—occur as soil efflorescences in many districts of scanty rainfall and low humidity in North India. The principal sources are: (1) the *reh* efflorescences of many parts of Bihar and Uttar Pradesh. The estimated potential yield of sodium salts annually available from the top layers of *reh*-infected soils of these parts is $1\frac{1}{2}$ million tons, made up of 600,000 tons of sodium bicarbonate, 500,000 tons of carbonate and 300,000 tons of sodium sulphate. (2) Sambhar, Didwana and Pachbhadra lakes of Rajasthan. The salt-bitterns of these lakes contain notable amounts of Na_2CO_3 and Na_2SO_4 in the upper layers of saline mud. At the bottom of these lakes millions of tons of these two salts are held. (3) The Lonar lake of Buldana district, Berar, contains alkaline mud at the bottom of the hollow with a few thousand tons of these salts. Though the quantity available is large, these salts have not found full industrial use. *Khari* the crude

industrial sodium sulphate, recovered from the Sambhar, Didwana and other lake brines of Rajasthan, and from refining of saltpetre, is employed in various chemical industries (about 20,000 tons refined yearly). The average annual imports of alkali salts from abroad amount in value to Rs. 7 millions. The consumption of soda-ash in India is 380,000 tons and that of caustic soda 360,000 tons, against produce of 300,000 tons and 140,000 tons respectively. The Indian demand is being increasingly met from indigenous raw materials. The upper layers of mud at the Sambhar and Didwana brine-lakes are capable of yielding several million tons of sodium sulphate and sodium carbonate.

Alum

Alums are not natural but secondary products manufactured out of pyritous shales or "alum shales". *Production*—Pyritous shales when exposed to air, under heat and moisture, give rise to the oxidation of the pyrites, producing iron sulphate and free sulphuric acid. The latter attacks the alumina of the shales and converts it into aluminium sulphate. On the addition of potash salts, such as nitre or common wood-ashes, potash-alum is produced, and when common salts or other soda-salts are introduced, soda-alum is produced. In this way several alums are made, depending upon the base added. The natural weathering of the shales being a very slow process, it is expedited in the artificial production of alum by roasting them. The roasted shale is then lixiviated and concentrated. A mixture of various soda and potash-salts is then added and the alum allowed to crystallise out.

The common alums produced in India are soda and potash alum, the principal consumers of alum in the country being the dyeing and tanning industries, where its use as an antiseptic and as an agent for cleansing water by coagulation of mud particles is common knowledge.

There was a flourishing industry in the past in Kutch, Rajasthan and parts of Punjab. It is no longer remunerative in the face of cheap chemically manufactured alums and is carried on

only at Kutch.

In Assam, dark coloured *pyritiferous shales* (see Pyrite) are recorded from several places in the coal-bearing horizons in Upper Assam and Khasi and Jaintia hills. It has been suggested that these shales could be used for the preparation of aluminium sulphates and alum, but the extraction of alum will probably be too costly to allow the establishment of a profitable business.

Soluble sulphates of iron and copper—copperas and blue-vitriol—are obtained as by-products in the manufacture of alums from pyrites.

Asbestos

Two quite different minerals are included under this name: one a variety of amphibole, resembling tremolite and the other, more important, a fibrous variety of serpentine (chrysotile). Both possess physical properties that make them valuable as commercial products.

Asbestos (amphibole) occurs in pockets or small masses or veins in the gneissic and schistose rocks. The chrysotile variety, which supplies 80% of the asbestos of commerce, forms veins in serpentine.

Asbestos has found a wonderful variety of uses in the industrial world of today. It is a naturally occurring silky fibrous material; but unlike other fibres, it is uninflammable and, therefore, invaluable in the manufacture of fire-proof cloth, rope, paper, millboard, sheeting, belt, paint, etc., and in the making of fire-proof safes, insulators, lubricants, felts, etc. It is also used in making aprons, gloves, curtains, brake-linings in automobile and like industries and insulating mats. Mixed with magnesia, it is used for making "magnesia bricks" used for heat insulation. Asbestos cement sheets are used for roofing. When asbestos is brittle, it is made into filter pads for filtering acids, organic liquids and other chemicals.

Occurrence of asbestos has been noted in the following areas:

Andhra Pradesh: Known in Telugu as *Ratinara*, asbestos of best quality is found in Pulivendla *taluk* of Cuddapah district. Here

excellent chrysotile asbestos occurs at the contact of a bed of Cuddapah limestones with a dolerite sill. There are several occurrences between Chitravati and Papaghani rivers. The 9½ mile long zone between Lopatanuthula and Brahmanapalle is the most promising.

For the years 1955 to 1965, the production has ranged from over 1,700 tons—2,700 tons.

Assam: Silky chrysotile, a commercial variety of asbestos has been recorded from the rocks in the Naga hills, especially between Puchimi and Kurami in Tezu valley near Manyung river, between Namyung and Taap (or Tepe) river, and near Gedu river.

Bihar: Asbestos occurs in over a hundred localities in Singh bhum district. Of these the deposits in Ṣeraikela and Dhalbhumgarh areas and those in the Dalama ranges are important. The possible reserves of asbestos in 32 localities so far estimated are of the order of 3½ lakh tons, upto depths varying from 20 to 100 feet. Much of the Seraikela region of Singhbhum, which is of the actionolite variety, however, does not possess that softness or flexibility of fibre on which its industrial application depends.

Gujarat: The few occurrences that are found in the State are in the Narayanpur valley in Sabarkantha district.

Madhya Pradesh: Asbestos occurs in thin veins in the limestone near Bachai in Narsinghpur district; there is possibility of finding workable veins in the neighbourhood. Asbestos also occurs in Jhabua district.

Madras: Small occurrences of fibrous asbestos are reported in the magnesite area near Salem. These are capable of development for manufacture of asbestos cement if sorting and grading of fibre is carried out accurately. The brittle variety of asbestos occurs in the magnesite area of Valiyapatti south of Namakkal in Salem district. Occurrences are also known in Nilgiri and Coimbatore districts.

Mysore: The main deposits occur in Hassan district. Asbestos in this area is of the brittle, amphibole type. Chrysotile variety of asbestos is known to occur in Mysore district.

Rajasthan: Important occurrences are known near Khewara and Rikhabdeo in Udaipur district, Jakol and Khymaru in Dungar-

pur district and Alwar and Kishangarh districts.

Uttar Pradesh: Occurrences are reported in Mirzapur district and at Jalai and Kanddhara in Garhwal district.

The available supplies of asbestos in India are sufficient to meet any expansion of the indigenous asbestos industry, the Andhra deposits being capable of considerable development for manufacturing asbestos-cement. About 2700 tons are now produced from Andhra and Seraikela zones yearly. Imports of raw and manufactured asbestos total over 30 million rupees worth annually, to meet her requirements.

India produced 2706 tons of asbestos in 1964 and imported 16,041 tons of raw asbestos during the same period.

Barytes

Barytes occurs in the form of veins and as beds in shales. The rather uncommon heavy mineral barytes is the sulphate of barium. Its uses are as a pigment for mixing with white lead, as a flux in the smelting of iron and manganese, in paper manufacture, in pottery glazes, etc. The whiter and better quality barytes is used in the local manufacture of paints (lithophone); the coloured variety is used in making heavy drilling mud (see p. 20 under "Clay") by the Oil Companies. It is also used in the manufacture of textiles, rubber, linoleum, gramophone records and printing ink. Barytes is calcined with carbon and the product is used in the manufacture of barium salts which have numerous uses known as "calcine" in industry and medicine. For instance, barium chloride, an important salt of barium, is used in water softening and in leather industry. Barium metal is utilised in electronic vacuum equipment.

The chief localities for barytes are:

Andhra Pradesh: There are two varieties, *viz.*, (i) Snow-white and (ii) buff-coloured (stained). The latter can be improved by appropriate treatment. It is found in Cuddapah, Anantapur, Kurnool and Khammamett districts. It has been estimated that Cuddapah district alone may contain 700,000 tons of barytes of all grades up to a depth of 100 feet.

Bihar: Barytes occurs at Kolpotke in Singhbhum district and in a few isolated localities between Ranchi and Purulia. The occurrences near Kolpotke appear to be promising for commercial exploitation.

Himachal Pradesh: The deposits occur in the form of veins and pockets in limestone south-east of Kanti and other localities in Sirmur district. Here the mineral is white, fine-grained and, for the greater part, appears to be very pure. The estimated reserves are of the order of 13,700 tons. This deposit, however, is remote from the nearest railway station, Jagadhari (Jamuna Nagar) in Uttar Pradesh. Barytes is also reported near Rajpur, Khajjar and Tatyana.

Madhya Pradesh: Barytes occurs as veins in copper lode at Sleemanabad in Jabalpur district and near Gairi and Rehti in Dewas district.

Madras: Numerous veins of barytes occur in North Arcot district. The mineral also occurs associated with celestite in a small area in Tiruchirapalli district. The amount is, however, too small to be commercially important. The mineral is also reported at Kurichchi in Coimbatore district.

Rajasthan: Barytes occurs at several localities in Alwar district and Hathori in Bharatpur district.

On the whole, barytes occurs in sufficient quantities, but, with few exceptions, the deposits were not worked till lately because of the absence of any demand for the mineral. The yearly output of recent years has risen to 40,000 tons valued at Rs. 8,75,000. With this yearly production the Indian deposits are considered adequate to meet the country's indigenous requirements.

BAUXITE

Besides its use as principal ore of aluminium (see "Aluminium"), bauxite is mined for various industrial purposes—manufacture of chemicals, abrasives, refractories, alum, high-alumina cement and in refining of petroleum. Annual requirement for these uses is about 250,000 tons. Available supplies are large; the better-grade bauxite averages 55% alumina, 28% combined water, 8%

titania, 6% ferric oxide, and below 3% silica in composition. India is capable of becoming a world centre of bauxite and alumina. (For further information see Section on "Aluminium".)

Borax

Borax occurs as a precipitate from the hot springs of the Puga valley, Ladakh, in association with some sulphur deposits.[1] It is of use in the manufacture of superior grades of glass, artificial gems, soaps, varnishes and in soldering and enamelling. Like the nitre, alum and similar trades, the borax trade, which was formerly a large and remunerative one, has seriously declined, owing to the discovery of large deposits of calcium borate in the U.S.A. from which the compound is now synthetically prepared. The former industry consisted of the importation of about 16,000 cwt. of partly refined borax valued at Rs. 3,60,000 from Ladakh and Tibet. The large resources of Puga are now projected to be refined locally for transport by air to industrial centres in India.

Corundum and Other Abrasives

Corundum is an original constituent of a number of igneous rocks of acid or basic composition, whether plutonic or volcanic. It generally occurs in masses, crystals, or irregular grains in pegmatites, granites, etc. The presence of corundum under such conditions is regarded as due to an excess of the base Al_2O_3 in the original magma, over and above its proper portion to form the original varieties of aluminous silicates. In these instances, corundum occurs as an original constituent of the magma, but the mineral also occurs, in many cases, as a secondary product in the zones of contact-metamorphism around plutonic intrusions.

Mostly corundum occurs in *situ* in the coarse-grained gneisses, in small round grains or in large crystals measuring some

[1] In Tibet, borax is an ingredient of many of the salt-lakes, along with other salts of sodium. The borax of the Tibetan lakes is obtained either by means of digging on the shores of the lakes or by the evaporation of their waters. The original source of the borax of these lakes is believed to be the hot springs like those of Puga.

inches in size. It also forms a constituent of the elaeolite-syenites of Sivamalai and of the coarse felspar rocks of Coimbatore.

USES

Corundum (transparent varieties used as gems have been mentioned, p. 114) is next to diamond in hardness; it is widely used in the manufacture of abrasives, a common example of which is the corundum powder-coated wheel of the knife-sharpener. Finely ground corundum blended with clay has been used for making refractory crucibles capable of standing high temperature. As an abrasive, corundum now has many rivals in such artificial products as *carborundum*, *alundum*, etc. Carborundum is used in the form of hones, wheels, powder, etc. by the lapidaries for cutting and polishing gems, glass, etc. Emery is an impure variety of corundum, mixed with iron-ores and adulterated with spinel, garnet, etc. The abrading power of emery is much less than that of corundum, while that of corundum in general is far below that of its crystallised variety sapphire. Deposits of corundum in India are known in the following localities:

Andhra Pradesh: The area around Punighi in Hindupur *taluk* is reported to have yielded large quantities of corundum for export. It is also available in Anantapur, in Kalyandrug and in Dharmavaram *taluks*. It also occurs near around Shankara mica-mine, near Griddalur in Nellore district. This area supplies the requirements of the leading abrasive factory at Madras.

Assam: Corundum occurs in association with sillimanite in Sonapahar in Khasi hills, an area not yet fully investigated. Corundum is believed to occur also below the alluvial tracts in Sonapahar area. Deposits containing several tons may also be traced in the Raindu river valley near the border between Garo and Khasi hills.[1]

Bihar: Localities notable for deposits are Singhbhum and Rewah

[1] In Burma, particularly in Mogok district (Ruby mines district), the famous ruby-limestone contains a notable quantity of corundum as an essential constituent of the rock, some of which has crystallised into the transparent varieties of the minerals, ruby and sapphire.

(Pipra), where a bed of corundum, 800 yards long, 70 yards wide and 30 feet thick is found.

Madhya Pradesh: Corundum is reported at a place about a mile from Paniari and in Morena district. Corundum of fairly good quality occurs in the corundum-sillimanite rocks about half a mile south-east of Pipra in Sidhi district, where pebbles of corundum are also recovered from the river bed. Small occurrences of corundum have been noted in Bastar district.

Madras: There is a large area of corundiferous rocks covering some parts of Tiruchirapalli, Nellore, Salem and Coimbatore. In Dharmapuri *taluk* of Salem district, corundum is found in a track forty miles long and one to five miles wide. Corundum has also been mined for over two centuries in Sittampundi area in Namakkal along a ten-mile belt with an average width of over a mile. Mostly the corundum occurs in *situ* in the coarse-grained gneisses, in small round grains or in large crystals measuring some inches in size. It also forms a constituent of the elaeolite-syenites of Sivamlai in Coimbatore district and of the coarse felds-par-rock of the district. Near Sivamalai, the occurrences of corundum are sporadic and have not been worked actively.

Mysore: India's large resources in corundum are mostly concentrated in Mysore State. Various grades of corundum, varying in colour as well, are found widely distributed here. In the Sringeri Jagir, small quantity of good ruby-corundum occurs. Large crystals of brown corundum have been found in places further south in the Ghat section. A number of deposits are found in Hassan district. On the eastern side there are several corundum-bearing areas in Pavagada *taluk*, Chitaldrug district. An important group of deposits occur in Tumkur and Kolar districts.

Indian corundum was in active demand for abrasive purposes before synthetic carborundum assailed the market. The varieties mined in Madhya Pradesh and Mysore State, being crystalline, are valued for their superior abrasive power. The total annual production in the country is, however, fitful ranging from about 4,000 cwt. to 10,000 cwt. Manufacture of abrasive wheels,

hones and discs is now an established industry in Mysore.

In 1963 , 600 tons of corundum were produced and most of it appears to have been consumed in the country.

OTHER ABRASIVES

Millstones

While dealing with abrasives, we may also consider here the materials suitable for millstones and grindstones that are raised in India. Massive garnet and garnet-sand occur in many parts of India, particularly abundant in Rajasthan, Bihar and in coastal sands, in sufficient quantity to be used as an abrasive. Flint has a hardness almost equal to garnet and is used in abrasive cloth and paper, and as flint-pebbles in grinding mills. Suitable material for abrasives occurs in most regions of India. Quartz-sand and quartzites, of universal occurrence in geological formations, are used in sand-blasting, glass surfacing and for burnishing. Fused alumina or bauxite, is a hard abrasive fit for grinding steel and other metals. A number of varieties of stones are quarried for cutting into millstones, though the rocks that are the most suitable for this purpose are hard coarse grits or quartzites. Compact siliceous slates and massive crystalline rocks are also used. There is a scarcity of such rocks in most parts of the country, production being intermittent and casual; hence the stones commonly resorted to are granites, hard gritty Vindhyan sandstones and Gondwana grits and sandstones chiefly of the Barakar stage.

Grindstones

Grindstones, or honestones, are cut from any homogeneous close-grained rocks belonging to one or other of the following varieties: fine sandstones, lydite, novaculite, hornstone, fine-grained lava, slate, etc.

The indigenous market for graded abrasives is expanding.

Feldspar

Feldspar is one of the commonest minerals in nature and is the basic raw material used in making porcelain articles including

the familiar porcelain cups and saucers. It is also used for the manufacture of earthen-ware, sanitary ware, enamelled bricks, opalescent glass and other kinds of glasses and in the facing of artificial building material. Finely ground feldspar bonded with ground quartz is used for making abrasive wheels.

Bihar: Important deposits associated with quartz are found south of Giridih-Madhupur railway line and near Karmatar and Mihijam railway stations of the Eastern railway. Most of the ceramic factories of Bihar and Bengal obtain their supplies of these minerals from there. Large quantities of feldspar occur also in the pegmatites of Bihar mica-belt. These, however, have no market in view of their prohibitive distance from the railway line.

Madhya Pradesh: Feldspar for commercial exploitation is found in Pegmatites which are widely distributed in the Archaean terrains of the State, but large deposits of feldspar free from impurities are rare. Feldspars have been worked in Sausar *tahsil* in Chhindwara district and at Lametaghat in Jabalpur district.

Madras: In Salem district coarse pegmatites containing workable feldspars occur near Idapaddi, and in many localities in Coimbatore, Nilgiri, Tiruchirapalli and Madurai districts.

Mysore: Feldspar containing 13% of potash is available in the pegmatitic veins in Shettiahalli, near Chikbanavar. Other sources of supply for the porcelain factories of Mysore are from Krishnapur in Hassan district, and in Bangalore, Mysore and Kolar districts. Feldspar occurs also near Matamari and Thurakankurthi in Raichur district.

Punjab: Good quality feldspar is available in pegmatites occurring in the Mahendragarh district.

Rajasthan: As an important mineral in mica-pegmatites, large quantities of feldspar are produced in the mica and beryl mines in Ajmer, Jaipur, Udaipur and Bhilwara districts.

Fluorite (Fluorspar)

Fluorite is calcium fluoride. It is colourless, white, greenish, purple, etc. The first-grade fluorite is used in enamelling iron for finishing enamel ware like bath-tubs, cte. and in the manufacture

of opaque and opalescent glasses and for the production of synthetic cryolite and hydrofluoric acid. The inferior grades of fluorite are used as flux in steel making and for foundry work. Transparent fluorite is used in increasing quantities for preparing lenses.

Madhya Pradesh: Fluorite occurs at Chandi Dongri in Drug district at Ghatkachar, Churakuta and Makarmuta in Mahasamund *tehsil* of Raipur district and at Rupand in Jabalpur district. The mineral occurs as a gangue in the copper lode at Sleemanabad, Jabalpur district.

Rajasthan: Occurrences have been recorded in the hills near Chowkri in Jaipur and in some places in Alwar, Ajmer and Kishangarh districts. Recently a big deposit of fluorite has been reported from Dungarpur district, estimated reserves of which exceed two million tons.

Veins of fluorite occur in the rocks of some other parts of the Peninsula and the Himalayas: at Khairgarh and Nandgoan in Madhya Pradesh, in the Vindhyan limestone in Rewah, in granite in the Sutlej valley, Simla Himalayas; but the output needs concentration by refining and flotation.

Garnet

The most familiar use of garnet is the abrasive paper for rubbing wood. (see "Garnet as a gem stone".) In Andhra Pradesh, parts of mica belt in Nellore, Krishna and Vishakapatnam districts have schists containing abundant well-formed garnet crystals.

In Madras State, many hundred tons of garnet occur in the sands of Ovari-Navaladi and Kuttankuli areas of Tirunelveli district. It occurs abundantly in the gneisses in North Arcot and Nilgiri districts. Massive garnet is found in some parts of Salem and Tiruchirapalli districts. Garnet is found in the beach-sands at places in Kanyakumari and Ramanathapuram districts.

In Mysore State, garnet has been reported from Tumkur district, in Mysore *taluk*, in Hassan district and in Holenarasipur taluk.

In Rajasthan, garnets occur near Sarwar and Rajmahal in Jaipur district and Phulad in Jodhpur district. Production of

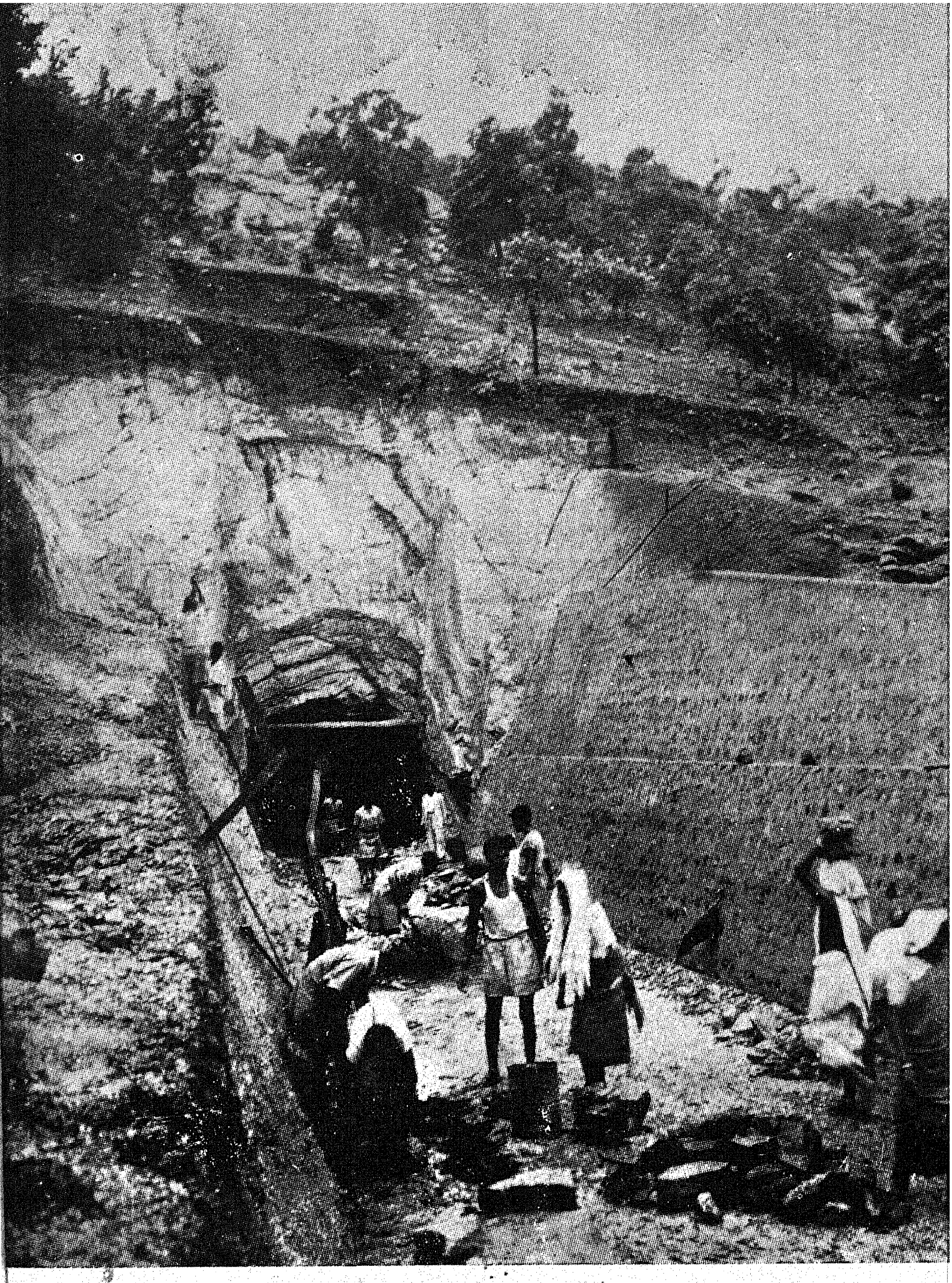


Fig. 9. Entrance to Uranium Mine, Jaduguda, Singhbhum

Fig. 10. AERIAL RADIOMETRIC SURVEY OVER MOUNTAIN TERRAIN FOR ATOMIC MINERALS

natural abrasives like garnet and quartz is intermittent and casual; but a local market for graded abrasives is expanding.

GRAPHITE

A naturally occurring, soft, light, blackish mineral with a metallic sheen and greasy feel, consisting of carbon, graphite is present (along with sillimanite and garnet) in the light-coloured richly garnetiferous gneisses and schists which form a group of rocks in Orissa and in Madhya Pradesh named "Khondalite". The khondalite is a rock-group of geographical prevalence, extending upto Kerala.[1]

Graphite occurs in small quantities in the crystalline and metamorphic rocks of various parts of the Peninsula, in pegmatite and other veins, and as lenticular masses in some schists and gneisses. Though it forms an essential constituent of the widely occurring khondalite in Orissa, a quartz-sillimanite-garnet-graphite-rock, the majority of the deposits are not of workable dimensions. Graphite occurring under such conditions is undoubtedly of igneous origin, *i.e.*, a primitive constituent of the magma or, more probably, a product of interaction of magmatic gases from igneous bodies (charnockites) with Khondalite and limestone. Graphite resulting from the metamorphism of carbonaceous strata, and representing the last stage of the mineralisation of vegetable matter, is practically unknown in India, except locally in some highly crushed Gondwana coal-beds in the Outer Himalayas.

The use of graphite lies in its refractoriness and high heat conductivity. It is, therefore, largely employed in the manufacture of crucibles, "brushes" in dynamos, moulds and it is also used as electrodes in electric furnaces. Being useful as moderator in nuclear reactors and Atomic Energy piles, it finds an important

[1] The same rock formation extends upto Ceylon where deposits of graphite are the largest. Ceylon has, in the past, supplied large quantities of this mineral to the world, its yearly contribution being nearly a third of the world's total annual produce. The graphite here occurs as filling veins in the granulites and allied gneisses belonging to the Khondalite series. The structure of the veins is often columnar, the columns lying transversely to the veins.

place in the atomic energy programme of some countries. Its other uses are in electrotyping, as a lubricant, and in the manufacture of some varieties of paints and colours, while its most familiar use remains in the manufacture of pencil, the blackish central rod (misnamed 'lead'), actually being a mixture of graphite and clay.

Graphite occurs in restricted quantities in the following areas:

Andhra Pradesh: The deposits are found in Vishakapatnam, East Godavari, West Godavari, Krishna and Khammamett districts. The State produces about 5% of India's output. It is worked in Khammam district, in West Godavari district, Vishakapatnam and Srikakulam districts. All these deposits are of low grade and have to be beneficiated before the graphite in them can be put to industrial use.

Bihar: Small deposits of graphite are worked at Daltonganj in Palamau district. Graphite is also reported to occur in some schistose rocks in other parts of Palamau and Hazaribagh districts.

Jammu and Kashmir: Amorphous graphite occurs associated with gypsum in parts of Uri Tehsil. It is found as impregnations in the phyllites. The great extent of the graphite-bearing phyllites indicates a large reserve of this mineral, but concentration of the mineral from the rock is likely to present difficulties.

Kerala: Till recently Kerala was an important centre for graphite-mining, supplying annually about 13,000 tons of the mineral (valued at Rs. 780,000). The industry has practically ceased of late years owing to the increasing depths to which mining operations have become necessary.

More recently, however, the Geological Survey of India has carried out detailed geophysical investigations in the area around old graphite workings near Vellanad in Nedumangad *taluk* of Trivandrum district. Massive high-grade graphite has been obtained in various trial pits. Considerable quantities of graphite were mined here before the First World War. The mineral is also reported to occur in parts of Quilon and Trichur districts.

Madhya Pradesh: A fairly large deposit of graphite occurs 3 miles north of Betul in Betul district. The mineral is worked at

Gauthana, Tikari and Chiklar. The material quarried is crushed and concentrated by washing.

Madras: A small deposit of graphite is known to occur in Tirunelveli district.

Mysore: A fine-grained amorphous type of graphite is obtained from graphitic schists near Ganacharpur in Bangarpet *taluk* in Kolar district. The mineral also occurs in crystalline schists near Mavinahalli and Torvalli in Mysore district.

Orissa: Sambalpur, Bolangir-Patna, Koraput and Dhenkanal districts are the graphite-producing areas of the State. In Bolangir district, nearly 56 workable deposits of graphite have been located so far in the Sadar, Patnagarh and Titilagarh sub-divisions. Several of these deposits are being worked at present and in most cases the quarries have gone down to a depth of 40 to 160 feet from the ground level.

In Athmallik sub-division of Dhenkanal district, there are quarries at Bamur and Dandatopa; here the crude graphite contains 70 to 80% of fixed carbon. The area between Dandatopa and Harirajpur needs thorough prospecting for locating more deposits.

Uttar Pradesh: Graphite is reported from Biuri, Ukkakot and Chira in Almora district and Mansori in Garhwal district.

West Bengal: Graphite occurs in bands of mica-schist over a belt about 2 miles wide and extending for over 40 miles eastwards from Purulia into Bankura district. It occurs in small flakes; but in some localities lumps of graphite have been obtained from the schists. Possibilities of commercial exploitation of these remain to be explored.

The quantity of graphite now produced in the country is not large. The present output is barely 2,000 tons per annum. Being mostly of low grade it has to be beneficiated before being put to industrial use, chiefly, crucible making.[1]

[1] As the parent rock-systems which carry the graphite deposits of South India and Ceylon show a close parallelism in composition, age and origin, the prospects of discovery of workable graphite bodies at numerous centres are not ruled out.

Gypsum

Gypsum is a hydrated sulphate of calcium. As a colourless or white opaque mineral in the form of massive lumps, or transparent plates, gypsum occurs abundantly in nature in sedimentary formations. In some cases it occurs as transparent crystals (selenite) associated with clays. Its large bedded masses or aggregates occur in association with rocks of various geological formations. Though it has, so far, not found a sufficient number of uses in India (as is shown by the low price of the product in some of its centres of production), it is now increasingly used as a source of sulphur for making fertilisers, either alone or in combination with natural manures. Gypsum, being a naturally occurring sulphate of calcium, finds its most popular use in making ammonium sulphate. It is also used as a surface-dressing for land with considerable benefit to certain crops. Gypsum is also an essential constituent of cement, though its proportion needed is only about 4%. Acting as an agent for slowing down the settling time of the cement, it improves its durability. The white, light, soft, easy-setting, fire-proof material used for surgical casts, called "plaster of paris" (dehydrated gypsum powder) is made by burning gypsum. In the U.S.A. it is increasingly used for fire-proofing wallboards as a building material. The handsome, massive, granular variety of gypsum, known as alabaster is used in Europe for statuary, while the silky fibrous variety, known as *satin spar*, is used as a medium for small ornamental articles. State-wise distribution of gypsum:

Andhra Pradesh: The only notable occurrence is that of crystalline gypsum (selenite) in the marine silts in the border area of Pulicat lake near Sulurpeta in Nellore district. The gypsum-bearing area, approximately 14 miles long and two miles wide, is estimated to contain 224,000 tons to a depth of 3 feet.

Gujarat: Important deposits occur in Bhavnagar district; near Miani and Keshau in Porbunder area, Kadiali in Junagadh district and in Jamnagar district. The reserves of Jamnagar district are estimated to be about 4.7 million tons. Extensive deposits of gypsum are found in Kutch district. Minor deposits occur near Bhilod, Dodwada and Wadagkhol in Kaira district.

Himachal Pradesh: In Spiti, Sirmur and other Himalayan areas, gypsum occurs in large masses replacing Carboniferous or other limestones. A number of fairly large pockets is known to occur in Sirmur district. The Bharli deposit is estimated to contain a total of 1,215,000 tons of rock averaging 41.71% of gypsum or 5,07,900 tons of the mineral. It is possible at present to work selected rich bands of this deposit for such industry as the manufacture of cement, plaster of Paris, potteries, etc. The main drawback of these deposits is their contamination with dolomitic limestone and shale which require to be removed in enormous quantities, and the distance from the nearest railhead, *viz.*, Jagadhari. These deposits supply the needs of big industries like the fertilizers, where half-a-million tons of gypsum of 90% purity are required annually.

Jammu and Kashmir: Millions of tons of gypsum, the alteration product of pyritous limestone of Salkhala age, are laid bare in the mountains of Uri and Baramula districts of Kashmir in a stretch of about 25 miles along the strike of the country rocks. In Uri Tehsil, where gypsum is associated with graphite rocks, the main locations are Lachhipura Bagna, Islamabad, Limba and Katha (Bombyar) Nalas. Here gypsum occurs in the form of alabaster (compact and fine-grained variety of gypsum). In Jammu area, large deposits of good-quality gypsum occur in Doda district near Ramban, Batote and Assan, as bands of varying thickness. This gypsum is usually massive and greyish-white. The reserves are estimated to be about 7 million tons. Drilling, now in progress, will throw more light on the reserves.

Madras: The most important deposit is in Tiruchirapalli district between Chittali in the north and Tappay and Periyakurukhai in south. It is estimated that, within a depth of 50 feet, over 15 million tons of gypsum are available. Minor occurrences are found along the coast and in some salt pans in Tirunelveli, Ramanathapuram, South Arcot and Chingleput districts.

Punjab: Deposits of gypsum occur in the Lower Spiti valley, especially on the left bank of the Spiti opposite Selkar (32°00' : 78°37'). Small pockets of gypsum occur near Subathu on the

border of Himachal Pradesh and Punjab.

Rajasthan: In the Tertiary clays and shales of the region important gypsum occurrences are met with in the localities of Jodhpur, Nagaur and Bikaner. Gypsum is quarried at Jamsar (estimated reserves 8,120,873 tons), Jaisalmer (estimated reserves 218,555 tons), Kaoni (estimated reserves 659,700 tons), Bharru (estimated reserves 583,000 tons). The average percentage of gypsum varies from 60 to 90 per cent. About one thousand tons of gypsum are transported daily from Jamsar to M/S Sindri Fertilizers and Chemical, Limited. Other occurrences are reported from Kavas, Kurlo and Shaokar in Barmer district and in Jodhpur, Jaisalmer and Nagaur districts.

Large deposits of the mineral have also recently been discovered by the Geological Survey of India at Nagaur and neighbouring areas. Gypsum here occurs generally below 140 feet from the surface and is of good quality, containing more than 75% of calcium sulphate.

Uttar Pradesh: Partly here and partly in Rajasthan area, beds of gypsum are found in old lacustrine deposits and are of considerable economic interest. The mineral occurs in Sera (north of Lachhamanjhoola) in Tehri Garhwal, Sohansdhara in Dehradun and Jharipani in Mussoorie and neighbouring places.

The available reserves of gypsum in the country are over 500 million tons. The production of gypsum in 1964 was over 1.2 million tons.

CHAPTER XIV

ECONOMIC MINERALS AND MINERAL PRODUCTS (Contd.)

Kyanite and Sillimanite

These naturally occurring aluminous silicates, owing to their possessing certain valuable properties as refractories at high temperatures in metallurgical industries, especially in the manufacture of ceramics and glass, have come into prominence of late years. They are also used in making sparking plugs in automobiles. Their distribution in India is restricted:

Assam: The deposits of sillimanite in Sonapahar occur as outcrops of natural rocks and boulders sometimes of big size. The Khasi hills sillimanite has an average content of 61% of alumina, 36% of silica, and, thus, very nearly reproduces the proportions considered ideal in the case of mullite and, therefore, is of very great value as a refractory material. Sillimanite occurs in beds of large size in the Archaean schists in the Khasi plateau. The recoverable reserves in Assam are of the order of 250,000 tons. The majority of the deposits consist mainly of massive sillimanite with a little corundum (which is a good agent for improving the quality of refractories). Rutile, biotite and iron ore are the only impurities.

Bihar: Kyanite occurs mainly in Singhbhum as kyanite-quartz rock and as massive kyanite-rock in beds of considerable size in the Archaean schists; sillimanite occurs also under similar conditions in the same-rock-system in the Rewah zone (Pipra village) of Madya Pradesh. Kyanite occurs along the northern flank of the copper belt for a distance of about 80 miles in Singhbhum district. The deposit of kyanite at Lapsa Buru near Raj Kharsawan is the largest in the world and also the best in quality. The reserves here are estimated to be of the order of 7,00,000 tons within a depth of a few feet.

Himachal Pradesh: Kyanite is abundant in the schists and

granites exposed near Kanaur and Bhabeh and in many parts of Bashaher where its beautiful colour has often led to its being mistaken for sapphire; but kyanite which occurs in blades is less hard than other refractories and breaks easily into small rectangular blades.

Madhya Pradesh: Deposits of Pipra region are estimated to contain 100,000 tons of massive sillimanite rock.

Mysore: Commercially workable deposits of kyanite occur in Hassan district. Corundum-kyanite rock near Makavalli in the same district contains 63% to 65% alumina and is being exploited. Quartzites of Bettabid in Mysore contain radiating nests of sillimanite up to one foot in diameter.

Orissa: Important workable deposits of kyanite are found in Kharsawan. They are also known to occur in Dhenkanal, Sundargarh (Bonai) and Mayurbhanj districts. The Panisia deposits in Mayurbhanj have been worked intermittently.

Rajasthan: Kyanite occurs near Kishangarh and Sansera in Udaipur district, Pansal in Bhilwara district and near Dewal and Warlia in Dungarpur district.

West Bengal: Bluish blades of kyanite occur in certain rocks of Darjeeling and Bankura districts. Possibilities of locating local concentrations of workable kyanite in certain areas remain to be investigated.

Total reserves of these minerals in India are computed at over a million tons so far. Corundum occurs with these in close relationship, forming a group of highly aluminous schists and gneisses. A high degree of purity, with percentages of aluminium silicate reaching 95 to 97, characterises both these minerals from Rewah, Singhbhum and parts of Assam. In 1964, 31,504 tons of kyanite and 12,417 tons of sillimanite were produced in India. Some years ago the entire output used to be exported without any processing or calcining. At present an embargo having been placed on its unlimied exports in the crude state, a part of the local requirements of processed refractory goods is met by indigenous manufacture. The present-day exports of kyanite are about 30,000 tons valued at Rs. 57,00,000 and of sillimanite 14,000

tons valued at about Rs. 8,00,000.

LIMESTONE AND DOLOMITE

Besides their use as building-stones and as raw material for lime and cement as described earlier, limestones, if they are of required purity, have important uses in the chemical, alkaline, sugar, paper, glass, leather tanning, and metallurgical industries. Slaked lime is an alkali and is an essential raw material in some chemical industries. Chemically pure limestones, containing over 96% $CaCO_3$, or free from harmful proportions of MgO, silica or iron, can be obtained from Katni, Maihar, Rewah, Bisra, Khasi hills, Jodhpur, Bikaner, Wardha and Chanda in North India and from several localities in Andhra Pradesh and Madras State. For use as a flux in iron-smelting, pure limestone, or in its absence, dolomitic limestone, is in constant demand.

DOLOMITE

Limestone with more than 10% $MgCO_3$ is called dolomitic; when the percentage rises to 45, they are true dolomites. Both these are fairly widely distributed in the Himalayas and other parts of India. Supplies from the former are readily available. Economic uses of dolomite in the country are chiefly metallurgical, as refractories (dead-burnt dolomite is used in furnaces for smelting iron, lead and copper); as blast-furnace flux; as a source of CO_2 gas and magnesium salts and other minor uses. The following localities may be noted for occurrence of dolomite:

Bihar: Dolomite occurs in bands to the north of Chaibasa in Singhbhum district and near Banjari in Shahabad district. Dolomite lying southwest of Daltonganj is associated with limestone bands.

Himachal Pradesh: The locations are in the Simla hills near Solan and in Mandi district where it is found in association with salt deposits at Maigal, Guma and Dorang. It is also found to occur as massive, grey dolomitic limestone of Shali series further south in the Sutlej valley of Suket.

Madras: Bands of chemical-grade calcite rock occur in some

of the crystalline limestones. Crystalline limestones of Salem and Tirunelveli are used for the manufactre of bleaching powder and other chemicals. Off the coast near Tuticorin, there are high-grade coralline limestone deposits which can be used for chemical industry.

Orissa: Deposits occur in Sundargarh, Sambalpur and Koraput districts. In Gangapur area, they occur near Sukra and extend for a total length of about 60 miles. In the Birmitrapur locality alone, the reserves of dolomite are of the order of 252 million tons of which about 84 million tons are of high-grade material. The deposits of Sambalpur district are estimated to have a reserve of about 5 million tons. The deposits of Koraput area are siliceous.

Punjab: Dolomite and dolomitic limestone occur in the Krol hill and the neighbouring hills of Solan and Barog in the Himalayas.

The resources of India in limestone and associated calcareous and dolomitic rocks are ample and capable of meeting all needs, *viz.*, manufacture of lime mortars, cement, fluxes and a wide variety of chemical uses. The use of chemical-grade limestone for calcium-carbide, chemical compounds such as lime-chloride and bleaching powder is increasing. For further information, see under "Limestone". In recent years the production of dolomite in India has been 170,000 tons valued at Rs. 94,00,000.

[*Limestone:* See Building Stones, Lime, Cement.]

MICA

Although muscovite (*i.e.*, white, or light-coloured potash-mica) is a most widely distributed mineral in the crystalline rocks of India, marketable mica is restricted to a few pegmatite-veins only, carrying large perfect crystals, free from wrinkling or foreign inclusions. These pegmatite-veins cross the Archaean and Dharwar crystalline rocks, granites, gneisses and schists; but they become the carrier of good mica only when they cut through mica-schists. Mica (muscovite) finds uses in many industries and is a valuable article of trade. The chief use is as an insulating material in electric goods, another as a substitute for glass in glazing and other purposes. As

a substitute for glass only large transparent sheets are suitable. As a transparent, fire-proof, non-breakable, elastic material, mica is suitable for making a variety of articles. Mica was known to the ancients who used it in certain Ayurvedic medicines. In modern times ruby-mica is used considerably in the electrical industry as an insulator because of its poor conductivity. Most rocks contain little specks of glistening mica; but these are not of use. To be useful, mica has to be in "books" of at least one-inch square size each, transparent and free from cracks. Formerly an enormous amount of *scrap-mica* (small pieces of flakes of mica), the waste of mica-mines and quarries, was considered valueless and was thrown away. A use has now been found for this scrap in the making of *micanite*—mica-boards—by cementing small bits of scrap-mica under pressure. Micanite is now employed for many purposes for which sheet-mica was formerly used. Scrap-mica is also ground for making paints, lubricants, etc. The mica deposits of the Indian Peninsula are considered to be the finest in the world, because of the large size and perfection of the crystal plates obtainable at several places. This quality of mica is due to its immunity from all disturbances such as crumpling, shearing, etc. of the parent rock. The dark-coloured ferro-magnesian mica, biotite, has no commercial use; but phlogopite (amber mica), occurring in Madras has industrial use as a heat and electric insulator. An alteration product of micas, which retains the micaceous cleavage, varying in colour from white to yellow, is known as "vermiculite". When heated its volume increases considerably (12 times or more) due to exfoliation. It is used where some extreme lightness, refractoriness and low-heat conductivity are required. It is also used in the manufacture of light-weight concrete for sound-absorbing panels. Some deposits of vermiculite have been located in Ajmer district of Rajasthan.

The principal mica-mining areas are:

Andhra Pradesh: Workable deposits of mica occur in Vishakapatnam, West Godavari, Krishna (Tiruvur), Khammamett (Kallur) and Nellore (Gudur) districts. The Kallur mica mine in Palvancha *taluk* was worked previously and later abandoned.

The Nellore mica belt, 60 miles long and 15 miles wide, is of world renown. Crystals more than a yard in diameter are obtained occasionally from the Nellore mines, from coarse pegmatite veins traversing Archaean schists and gneisses, from which valuable flawless schists of great thinness and transparency are cloven off. This area is also the second largest producer of muscovite mica in India. Its mica has a characteristic light greenish colour. The yearly production exceeds 17 million lbs. The Shah mine in Gudur is the deepest, its depth being 1,000 feet, where the mica-bearing pegmatite is said to have pinched out. The mining here dates back to 1889. The bulk of the production from the State is of black-spotted mica, known as "Electrical Mica".

Bihar: Bihar is the most important producer of ruby mica in the world. The mica-belt here extends for about 90 miles in length from the eastern part of Gaya district, across Hazaribagh and Monghyr to Bhagalpur district. This belt is about 20 miles in width and conatins, perhaps, the richest deposits of high-quality ruby mica in the world. The main centres of mica production in the belt are in Kodarma reserve forest, Dhorhakola, Domchanch, Dhab, Gawan, Tisri, Chakai and Chakapathal (Mahesri). The mica 'books' are sometimes 3 feet square in size, the average size being about a foot square. The crude mica is dressed into blocks of standard size. The smaller splittings are made into micanite at the micanite factory at Jhumri Talaiya. In the pegmatite veins in the Hazaribagh region, lepidolite, lithia mica, the source of lithium oxide, occurs; it contains 2-3% lithium oxide which is of use in the chemical, glass and porcelain industries and is also of use in development of atomic power.

Gujarat: Mica occurs in Banaskantha district, in Gabodia hills in Chhota Udepur, Baroda district and in Devgad Baria, Panch Mahals district, in Sabarkantha district. The occurrences are sporadic in nature and do not hold promise for commercial exploitation.

Kerala: Muscovite mica is reported to occur in Trivandrum district, and in small pegmatites in Alleppey district. Phlogopite mica is known to be present in some parts of Quilon district

and near Trivandrum.

Madras: Small deposits are known to occur in Gudalur *taluk* of Nilgiri and in parts of Salem district. A few mica-bearing areas are also known in Tiruchirapalli district which are awaiting exploration.

Madhya Pradesh: Workable deposits of mica have not hitherto been reported, though pegmatitic rocks in which this mineral usually occurs are widely distributed. Attempts to work mica have been made in Balaghat district, and in Bilaspur district. Small-size mica with flaws occur in pegmatites in the Narsinghpur and Chhindwara districts. A large development of lepidolite mica has been met with in Bastar district. This lepidolite occurs in lenses 30 feet wide and 300 to 400 yards long and is of considerable economic importance.

Mysore: Books of mica, upto seven to eight inches in thickness have been found in many places; but the distribution is very erratic. Much of the material has flaws or spots and is of poor quality.

Rajasthan: Mica-mining in this State came into prominence after the First World War. Its most important centres are in Bhilwara, Udaipur, Jaipur and Tonk districts. The less important areas are in Alwar, Bharatpur, Jodhpur, Kishengarh and Sirohi districts.

Uttar Pradesh: The few mica deposits known so far possess poor-grade greenish mica with cracks and stains. These are found in Bandi Khal and Kunet district while small books of ruby mica are reported from Mirzapur district. These occurrences merit further investigation.

India is the largest producer of mica in the world, contributing, of late years, more than 75% of the world's requirements. Of the estimated world supply of muscovite block-mica and mica splittings, India produces about 80%. It appears likely that, despite the threat of synthetic mica, certain grades of Indian mica will remain vital to the world's electrical industries. The export of mica during the post-War years has increased in quantity from an average of 1,70,000 cwts. (of block and splittings) to

about 6,00,000 cwts.; in 1950 the value realised was over Rs. 120 million. Since then the export has fluctuated a great deal. Scientific mining methods and mechanisation of mines with increasing depths of the pegmatites, and rigid control of the standards of dressing and grading of finished mica (to meet the requirements of foreign trade), together with local processing of part at least of split and block mica, are urgently needed reforms. The use of ground mica for firebricks, paints, etc. from the huge dumps of scrap and the manufacture of micanite from the waste of mines and factories will make this important mineral industry of India more profitable. At present, most of the output of mica is exported, since indigenous electrical and other industries cannot sufficiently absorb the output. In 1963, India produced 26,454 tons of mica, out of which about 24,000 tons were exported. It has been a valuable foreign exchange earner which, in its turn, makes the industry entirely dependent on foreign demand. Such demand has often threatened to decline. The industry can be put on a firm footing by furthering the development of electric industries in the country.

Mineral Paints

A number of rock and mineral substances are employed in the manufacture of paints and colouring material in Europe and America. Substances which are suitable for this purpose are earthy forms of haematite and limonite (ochres, *geru*), refuse of slate and shale quarries possessing the proper colour and degree of fineness: graphite, laterite, orpiment, barytes, asbestos, mica, steatite, etc. Many of these substances are easily available in various parts of India and some are actually utilised for paints and pigments, *viz.*, a black slate for making black paints; laterite and *geru* (red or yellow levigated ochre) for red, yellow or brown colouring matters; barytes as a substitute for white lead; orpiment for yellow and red colours in lacquer work. The Indian village population is familiar with the red and yellow clayey materials—ochres—mostly used in paints, colourwashes and wall plasters.

Locality-wise the materials for mineral paints are found in:

Andhra Pradesh: Ochres are found in Cuddapah, Kurnool, West Godavari, Vishakapatnam and Hyderabad (Vicarabad area) districts. Yellow ochre-deposits are known to occur in Kurnool district.

Gujarat: The main ochre deposits are mainly of two varieties: (1) those associated with laterite, in which they occur as irregular pockets and (2) those associated with bedded rocks where they occur as extensive beds of fine-grained, coloured clays without any gritty material. The lateritic clays are found in Bhavnagar district and at a number of places in Jamnagar district. Deposits of the second category are extensive. In Zalawad district they occur down to a depth of 15 feet from the surface; the reserves are calculated to be about 3 million tons and the quality compares well with some of the imported ochres. Similar occurrences are also reported from some adjoining localities. Yellow ochres of excellent quality are found in Porbander district and cover an area of a quarter of a square mile. The material from this deposit finds a regular market. Extensive deposits of ochres also occur in Rajkot district. The ochres from these localities are worked, levigated and used for manufacture of paints. Commercial-grade ochres are also found in Kutch district in micaceous haematite occurring near Joywas Railway Station, Baroda district. Red and yellow ochres occurring in Broach district are reported to have been worked for many years. At present the ochres from Gujarat are utilised in the manufacture of paints and varnishes, but there is further scope for the development of this industry.

Jammu and Kashmir: Large quantities of red and yellow ochre in association with the black graphite-bearing slate occur in the Salkhala system of deposits in Uri Tehsil of Kashmir region, as isolated surface deposits. About 2,00,000 tons of ochre are estimated in the Nur Khawh and Ratasar areas which merit more attention.

Madhya Pradesh: Occurrences of red ochre have been reported from Drug district, Balaghat district, Jabalpur district and Gwalior district. Green earth is known to occur in a few localities in the districts of Rajgarh, Ujjain and Dewas.

Madras: Red and yellow ochres are found in parts of Madurai, Ramanathapuram, Tiruchirapalli and North Arcot districts.

Maharashtra: Coloured earths associated with laterite occur near Ratnagiri district. There is no dearth of bedded red earth in the Deccan Trap country, where there is a large scope for finding rich beds throughout Maharashtra. The extensive spread of laterite in the districts of Ratnagiri, Kolhapur, Kolaba and Satara is likely to contain numerous pockets of red and yellow ochres.

Mysore: A vast quantity of intensely red earthy haematite lies scattered over the western base of the Ramandrug section of the Sandur hill group. Red oxide with 99.8% of ferric oxide occurs in Bellary district. Associated with iron and manganese ores and limestones in the Tumkur district occur ochres of many shades of yellow, red and brown.

Ra asthan: Red and yellow ochres are found in large quantities, the main deposits being located in Bharatpur, Bundi, Dungarpur, Jaisalmer, Tonk and Udaipur districts.

MONAZITE

Monazite is a source of rare earths of the cerium group, of phosphoric acid and of thorium oxide. Monazite is a phosphate of the rare earths, cerium, yttrium, lanthanum, didymium, *etc.*, with a variable percentage of thorium and uranium oxides, which it contains as an accessory. It is a portmanteau compound carrying some 15 rare-earth oxides. Monazite occurs in the ilmenite sand of the beaches, brought there by rivers draining the hinterland and concentrated by wave action on the littoral. It is found as beach-sand along with ilmenite over long stretches of the coast-line, both on Malabar and Coromandal coasts. On the Travancore beaches, wave action has concentrated these heavy mineral sands into rich placers. Monazite is derived from the pegmatite-veins crossing the Charnockites and allied rocks of Nilgiris and Western Ghats. Its origin is ascribed to pneumatolytic agencies during the later period of consolidation of the igneous magma. Monazite is also a small constituent of the main granitic and gneissic rocks

of the area. Monazite is the most important source of thorium metal, considered to be the atomic fuel of the future (dealt with in a subsequent chapter). Other industrial uses of monazite are in the incandescent properties of thoria, in the oxide of the rare-earths, in alloys with magnesium metal, and in the preparation of certain medicines. The silky, net-like gas mantles are made of silk dipped in thorium salts and dried. Thorium has a limited industrial application in photo-electric cells and X-ray.

Andhra Pradesh : Monazite associated mainly with magnetite, zircon, garnet and ilmenite is found as concentrates in the beach-sands of Vishakapatnam.

Kerala : Monazite and thorianite (with uranothorianite) are present in the beach sands of the State. The beach concentrates occur in bays between rocky headlands. The main deposit is near Chavara, north of Quilon, some hundred thousand tons being present there. The average monazite content of these beach sands is about 1%, the percentage of thorium in monazite being 8.5% ThO_2.

Madras: The occurrences of sands containing monazite along with zircon, garnet, rutile, sillimanite, ilmenite near Cape Comorin (Kanya Kumari) and in the coastal areas of Tanjore district are well known. These, however, await detailed investigation. The pegmatites and granites of Salem, Coimbatore and Madurai districts are likely to carry radioactive minerals.

Ranchi Plateau (Bihar) : Some hundred thousand tons of monazite sand occurring along with ilmenite and zircon as an alluvial deposit in the soil-cap covering areas in the Ranchi and adjoining Purulia district has been observed.

The percentage of thoria in monazite varies from 8 to 10.5%, together with 0.3%—0.4% of U_3O_8. In the newly discovered mineral *cheralite* (p. 167) found in some pegmatites in Kerala, it ranges from 19 to 33%, with 4 to 5% of U_3O_8.

The present annual output of monazite is 1500 to 2000 tons, mainly employed in the manufacture of cerium compounds, the thorium and uranium being recovered for use as atomic fuels. The total Indian reserves of monazite are now estimated at over 5

million tons, one of the largest concentrations of thorium in the world, most of it occurring in the readily accessible form of sands.

PHOSPHATES

Native phosphates, as apatite or rock-phosphates, as concentrations, are highly valued now as artificial fertilisers or manures, either in the raw condition or after treatment with sulphuric acid to convert them into acid or super-phosphates. The mineral apatite and phosphatic rock-nodules are grouped in this category. Phosphorus is an essential ingredient in building up the fertility of soil. The depletion of this element in soils renders them less productive and it is, therefore, supplemented by the modern farmer by adding fertilisers containing super-phosphate and nitrates. Super-phosphate can be manufactured from the mineral apatite, a naturally occurring phosphate of calcium. Phosphorus has a wide variety of other uses, as in the manufacture of matches, chemicals, plastics and medicines; apatite is one of the natural sources of this important element.

Bihar: Massive apatite occurs as an abundant constituent of the mica-pegmatites of Hazaribagh and of the mica-peridotite dykes in the Bihar coal-fields. Fairly large deposits of apatite also occur over a belt of 40 miles in the southern part of Singhbhum district. About 6 to 7 lakh tons of apatite-rock are estimated to be present in these areas. These rocks contain, on an average, 20 to 25 percent P_2O_5. Phosphatic deposit is also found in *lenticular aggregates* in the Dharwar rocks of Dalbhum, in Singhbhum, where the phosphate is estimated to be present in 250,000 tons quantity.

Madras: Phosphatic deposits occur in connection with the Cretaceous beds of Tiruchirapalli, where phosphate of lime occurs in the form of septarian nodules disseminated in the clay-beds (P_2O_5—15 to 20 percent). The quantity available is about 8,000,000 tons. About two million tons of these are estimated to occur at a depth of 50 feet and, therefore, considered economically recoverable. Apatite also occurs in some schistose rocks in the State.

Maharashtra: Like Madras State, apatite occurs in some schistose rocks in a small quantity.

Uttar Pradesh: Deposits overlying the Deobund limestone near Mussoorie are rich in tricalcium phosphates. They occur in the form of nodules and layers. The nodules contain 76% calcium phosphate, while the phosphatic rocks contain about 65%.

It is regrettable that in a country like India whose primary industry is agriculture, there should be a paucity of natural phosphates. The only occurrence of phosphatic deposits on a sufficient scale is in connection with the Cretaceous beds of Tiruchirapalli described above. A source of phosphorus for use as mineral fertiliser exists in the basic slags formed in the manufacture of steel. Over 50,000 tons of this slag (P_2O_5 10%) are dumped annually at the Steel Works for want of any present demand. Super-phosphate manure in India is manufactured from rock-phosphate (imported from Morocco and Florida) and bone-meal to the extent of some 110,000 tons per annum. The consumption of chemical fertilizers, however, is steadily rising and the manufacture of about 800,000 tons per annum of synthetic ammonium sulphate and 300,000 tons of super-phosphate is trying to meet the demand.

Pyrite

Pyrite, sulphide of iron is a mineral of very wide distribution in many formations from the oldest crystalline rocks to the youngest sediments. The economic value of pyrite lies in its being a source of sulphur and not as an ore of iron, because the high proportion of sulphur in it is injurious to the iron. The occurrences on any considerable scale are those of the pyritous shales deposits lately found in the lower Son valley at Amjor, Bihar; in Chitaldrug district of Mysore and the pyritous coal and shale of the Assam coalfields. No attempt was made to develop the elemental sulphur from these deposits because of the cheapness of imported sulphur. With short supplies of foreign sulphur, of late, the manufacture of sulphur and sulphuric acid, from the large Amjor pyrite deposit, is projected. An output of 100,000 tons of sulphur is being planned. Large stores of sulphur exist in connection with metallic sulphides, notably those of zinc, copper and lead, which, if they can be worked in India for the recovery of the metal, will liberate the sulphur as

well in large amounts. The reserves of pyrite at Amjor are computed at nearly 400 million tons.

QUARTZ

Quartz, Silica (SiO_2) is the most abundant mineral in the rocks of the Earth's crust. It builds massive formations, such as quartzites and quartz-reefs, occurring as veins over long distances. River-sands, sea-sands are composed of over 90 per cent quartz. Quartz in crystals (rock crystals) is of value as piezo-electric mineral and optical material, for lenses etc. Quartz crystals of a certain type are used in the radio to control the frequency of radio circuits. Transparent and coloured varieties of crystalline quartz, when free from flaws, are used as precious stones (See Chapter XII).

Quartz sands have numerous uses as building sand, moulding sand for foundry use, refractory sand for furnace use, glass sand for glass-making; sand for grinding and polishing, fire-proofing, sound-proofing, etc.

One of the largest uses of pure silica sand is in glass-making. Next to glass-making quartz sand is employed in making refractory silica bricks for glass furnaces and coke ovens.

Massive crystalline quartz veins and pegmatite veins occurring in Andhra, Bihar and Rajasthan on a large scale are an important source of quartz and silica of great purity employed in various industries.

Madhya Pradesh: Quartz-veins or reefs (the ultra-acid modification of the pegmatite-veins) of great length, run as long, narrow, serrated walls, intersecting each other in all directions, giving to the landscape of the country a peculiar feature. They contain abundant supply of pure silica.

The total present output of quartz and silica is 24,000 tons, value Rs. 25.5 lakhs, per annum.

CHAPTER XV

ECONOMIC MINERALS AND MINERAL PRODUCTS (Contd.)

REH OR KALAR

THE ORIGIN OF THE SALTS

REH, USAR or KALAR are the local names of a saline efflorescence composed of a mixture of sodium carbonate, sulphate and chloride, together with varying proportions of calcium and magnesium salts, found on the surface of alluvial soils in the drier districts of the Gangetic plains. At present, *Reh* is not an economic product, but it is described here because of its negative virtues as such. Some soils are so much impregnated with these injurious salts that they are rendered unfit for cultivation. Large tracts of the country, particularly in northern parts of Uttar Pradesh, Punjab and Rajasthan, once fertile and populous, are through its agency thrown out of cultivation and made desolate. The cause of this impregnation in the soil and the subsoil is that the rivers draining the mountains carry with them a certain proportion of chemically dissolved matter, besides that held in mechanical suspension, in their waters. The salts so carried are chiefly the carbonates of calcium and magnesium and their sulphates, together with some quantity of sodium chloride, etc. In the plains-track of the rivers, these salts find their way, by percolation, into the subsoil, saturating it upto a certain level. In many parts of the hot alluvial plains, which have got no underground drainage water, the salts go on accumulating and in the course of time become concentrated, forming new combinations by interaction between previously existing salts. Rain water, percolating downwards, dissolves the more soluble of these salts and brings them back to the surface during the summer months by capillary action, where they form a white efflorescent crust when the solutions evaporate. The reclaiming of these barren

kalar lands into cultivable soils by the removal of these salts would add millions of acres to the agricultural area of India, and bring back under cultivation what are now altogether sterile, uninhabited districts.

Reh is found in the following parts of India:

Andhra Pradesh: Stretches of *reh*-covered soil occur in Guntur district and in Anantapur district. One sample from Kakinada in East Godavari district contained 50-56% sodium carbonate, 32.96% sodium chloride and 16.48% sodium sulphate.

Bihar: Different types of alkali salts are locally known as *reh*, *saji matti* and *khari*. They occur in Kharan, Champaran, Muzaffarpur and parts of Monghyr and Gaya districts.

Madras: *Reh* which contains a large amount of sodium salts, collects as an efflorescence in the soils occurring in Salem district, Perambalur *taluk* Tiruchirapalli district and in South Arcot and Ramanathapuram districts. The soils in and around Mohanpur and Velur in the Cauvery valley of Salem district contain a good proportion of nitrates, which are collected as efflorescence. The salts are recovered by dissolving the efflorescence in water and evaporating the filtrate. This is a cottage industry with a bright future.

Uttar Pradesh: Extensive *reh*-covered tracts occur in Hasanpur, Moradabad district, along the western side of the Ganges in Muzaffarnagar district and in parts of Meerut district. Large amounts of *reh* salt are recovered every year from these places. The carbonate and sulphate of sodium, the chief constituents of *reh*, were formerly produced in some quantities (as a source of salts & alkalies) for local industry. Their production on an industrial scale for utilisation in the expanding chemical industries of the country is being extended.

SALT

Source of Salt

There are three sources of production of this useful material in India: (1) Sea water along the coast of the Peninsula; (2) brine-springs, wells and salt-lakes of the arid tracts, as of Rajasthan and

Uttar Pradesh; (3) rock-salt deposit contained in Kutch and in Mandi region (Himachal Pradesh).

Salt is one of the most common substances of use in daily life and is indispensable for several modern industries.

Assam: Although salt-lakes are common in the Barail rocks, no substantial deposits have yet been recorded in them. The climate of Assam is too moist to allow the formation of any superficial saline efflorescence. At present salt is derived (and locally used) from the brine wells (known as "Pung") fairly common in the Naga hills. Brine springs also occur in Cachar district in various places and salt was formerly prepared in the Sadia and Jorhut areas in early days. The salt lakes and other local sources of salt of Assam require further investigation.

Gujarat: Most of the salt in Gujarat is produced by direct solar evaporation of sea water. An appreciable quantity of salt is also derived from subterranean brine in the Little Rann of Kutch. The important salt producing centres are: Rajkot district; Jamnagar district; near Porbandar and Mongrol; Surat district; Bhavnagar and Zalawad district.

Some millions of tons of pure rock-salt, produced by evaporation of sea-water in enclosed basins, occur embedded in the sands of the Rann of Kutch. The same process extends to the alluvial tracts of the south-eastern boundaries of Sind, Pakistan.[1]

Himachal Pradesh: The rock-salt deposits of Mandi are in

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[1] *Rock-salt Mines of Khewra, Pakistan:* The rock-salt deposits of West Pakistan also constitute a prolific source of pure crystallised sodium chloride. At Khewra, in Jhelum district, two beds of rock-salt 550 feet thick are worked; they contain five seams of pure salt totalling 275 feet, intercalated with only a few earthy or impure layers unfit for direct consumption. The horizontal extension of these beds or lenticles is not known definitely, but it is believed to be some miles. Small salt-mines are situated at some other places along the Salt-Range. A salt deposit of even greater vertical extent than that worked at Khewra is laid bare by the denudation of an anticline in Kohat district, north-west of Salt-Range. Here the salt is taken out by open quarrying in the salt-beds at the centre of the anticline near Bahadur Khel. The thickness of the beds is a 1000 feet and their lateral extent about 8 miles. The salt is nearly pure crystallised sodium chloride with a distinct greyish tint owing to slight bituminous admixture.

a zone of limestones, shales and sandstones. Salt beds of considerable size occur here. Crystalline salt is occasionally met with. The average annual production from Mandi mines is fluctuating; in some years it reaches 4,400 tons.

Maharashtra: Salt is manufactured at Shiroda in Ratnagiri district; in Kolaba district; in Thana district; and Bombay. Yearly production figure is 485,000 tons.

Punjab: The groundwater is saline in parts of Sultanpur Mahal in Gurgaon district and in Rohtak district. Salt extraction from this water is under consideration.

Saltpetre occurs in the districts of Ferozepur, Amritsar, Hissar and Rohtak. Production of this, however, is affected by the cheaper saltpetre imported from Chile.

Rajasthan: Considerable quantities of common salt are prepared from brine. The important areas of production are the salt-lakes of Sambhar in Jaipur division Didwana, Phalodi and Pachbhadra lakes in Jodhpur division and Lonkarasar in the Bikaner division. The salinity of the lake in this area of internal drainage has, for long, been a matter of conjecture as to whether it is of local origin, or is due to constant dropping of wind-borne salt as dust from the Coast or from the Rann of Kutch. Of the salt-lakes of Rajasthan, the Sambhar lake is the most note-worthy. It has an area of 90 square miles when full during the monsoon, when the depth of the water is about 4 feet. For the rest of the year it is dry, the surface being encrusted by a white, saliferous silt. (The cause of the salinity of the lake was ascribed to various circumstances, to former connection with the Gulf of Cambay, to brine springs, to chemical dissolution from the surrounding country, etc. But a series of experiments by Geological Survey authorities showed that the salt of the lake of Rajasthan is largely wind-borne. About 130,000 tons of saline matter is calculated to be borne by the winds annually to these lake areas by the winds during the hot weather months. From a recent examination of the data regarding direction and strength of surface and upper winds in this region, however, it appears unlikely that a great proportion of the salt could have been wind-borne from the Kutch littoral.)

The Sambhar lake is known to have a large reserve of salt in its bottom layers of mud and silt. Up to a depth of 12 ft. the reserves are computed at 50 million tons. An old salt manufacturing centre at Bharatpur is reviving fast.

The average annual production of salt from the above sources is rather over two million tons, the whole of which is consumed in the country. Of the other sources of obtaining salt, sea-water is the most productive and an ever-lasting source, which contributes about 75% of the salt consumed in India. The manufacture is carried on at places along the coasts of Bombay and Madras, the process being mere solar evaporation of the sea-water enclosed in artificial pools or natural lagoons. A solid pan of salt results, which is afterwards refined by recrystallisation. Concentration from brine springs and wells is carried on in various parts of Uttar Pradesh, Bihar, Kutch, Rajasthan, Delhi and Agra regions. These resources hardly meet the country's annual requirements of domestic and industrial salt totalling about 5.5 million tons. 4 million tons are supplied by sea salt, 400,000 tons by brine and lake salt, 4,500 tons by rock-salt, and the deficit by imports.

Other Salts

Besides sodium chloride some salts of magnesium and potassium are useful in agriculture and some industries.

Saltpetre or Nitre (potassium nitrate)

The chief use of nitre or saltpetre was in the manufacture of gunpowder and explosives, before the discoveries of modern chemistry brought into use other compounds for these purposes, and as an oxidiser in numerous chemical processes. A subordinate use of nitre in India is as manure for the soil.

Saltpetre is a natural product formed in the soil of the alluvial districts by natural processes under the peculiar conditions of climate prevailing in those districts. The thickly populated agricultural province of Bihar, with its alternately warm and humid climate, offers the most favourable conditions for the accumulation

of this salt in the subsoil. The large quantities of animal and vegetable refuse gathered round the agricultural villages of Bihar are decomposed into ammonia and other nitrogenous substances; these are acted upon by certain kinds of bacteria (*nitrifying* bacteria) in the damp hot weather with the result that at first nitrous and then nitric acid is produced in the soil. The nitric acid readily acts upon the salts of potassium with which the soil of the village is impregnated on account of the large quantities of wood and dung ashes constantly heaped by villagers around their habitations. The nitrate of potassium thus produced is dissolved by rain-water and accumulated in the subsoil, from which the salt re-ascends to the surface by capillary action in the period of desiccation following the rainy weather. Large quantities of nitre are thus left as a saline efflorescence on the surface of the soil along with some other salts, such as chloride of sodium and carbonate of sodium.

In the past years Bihar State alone used to produce more than 20,000 tons of nitre per year, valued at Rs. 10 million. The present export of nitre from Bihar, Punjab and other parts of India is insignificant.

Steatite

Steatite (Talc) is of wide occurrence in India forming large masses in Archaean and Dharwar rocks of the Peninsula. In its geological relations, steatite is often associated with dolomite (as in Jabalpur) and other magnesian rocks, and it is probable that it is derived from these rocks by metamorphic processes resulting in the conversion of the magnesian carbonate into the hydrated silicate. In other cases it is the final product of the alteration of ultra-basic and basic eruptive rocks.

Being massive, compact, structureless and easily-scratchable, steatite is put to a number of uses. Because of its smooth, uniform structure and soapy feel, it is popularly known as "soapstone", sometimes called "potstone" from its being carved into bowls, pots, plates and other shapes. Besides these and its use in ornamental work in building, it has application in industry, the lava-grade material being very much in demand in the preparation of low-cost

ceramic material used in radio, radar, television and related instruments. It is also used in paints, ceramics, paper industry, soap-making, textiles, in the preparation of talcum (cosmetic) power and as a refractory substance in making jets for gas-burners. High grade steatite is used in making special procelain. Steatite has of late come into use as a special type of refractory, resistant to corrosive slags, and as a paint for high quality for protecting steel.

Localities of Steatite

Andhra Pradesh: In Anantapur district, a very fine variety occurs; the estimated reserves are a little over 50,000 tons. There are also several other occurrences of steatite in the Kurnool, Nellore and Karimnagar districts. The steatite from Kurnool district is said to be of "Lava-grade".

Madhya Pradesh: Steatite occurs in large quantities in the "Marble Rocks" near Jabalpur. There are also deposits near Rupaund on the Katni-Bilaspur branch of the South Eastern Railway. A workable deposit of talc occurs near Kumbi in Alirajpur, Jhabua district.

Madras: Soapstone (steatite) occurrences are known near Tiruchirapalli district and from Omalur taluk of Salem district.

Orissa: Deposits occur in Balasore (Nilgiri), Sundargarh (Bonai), Cuttack (Sukinda) and Keonjhar districts.

Rajasthan: The larger deposits of superior quality steatite occur in Gisgarh, Morra-Bhanderi and Dogeta in Jaipur district, and Jeoria (Ghevaria), lakhavali and Deopura in Udaipur district. Minor occurrences are recorded from Alwar, Banswara and Dungarpur districts.

Uttar Pradesh: It occurs in association with magnesite deposits in Bhageshwar, Deolthal, Deoldhar, etc. in Almora district. A mineral similar to soap-stone in some of its properties, pyrophyllite, is found at Garahri in Hamirpur district and near Bijri and Dhaukua in Jhansi district.

West Bengal: Small occurrences of talc are located on the hill slopes of the Darjeeling Himalayas near the Sikkim border, at a

distance of about a mile north of Gokbaer and about 10 miles north-west of Darjeeling town. The material varies in quality and grades from impure greenish variety to white massive talc. Some of these pockets have been quarried since 1952.

Numerous occurrences of talcose-chlorite-schists and talcschists have been noticed in Bankura and Jalpaiguri districts. These rocks are suitable for use as potstone and are locally used for carrying out pots and utensils of various designs.

Of the above described occurrences the reserves of good-quality steatite in Jabalpur region (Madhya Pradesh) and Jaipur regions (Rajasthan) are notable; the annual production at the latter at present is about 100,000 tons with a value of over Rs. one crore. The Indian production of steatite in 1964 amounted to 122,000 tons, one-sixth of which was exported. Given vigorous attention to grading according to specification and adoption of modern milling methods, India should be in a position to meet a fair part of the world's trade in this mineral which is rising in demand.

Sulphur

Sulphur occurs in natural state as glistening yellow crystals. It also occurs in combination with other metals as sulphides, such as the golden yellow iron-sulphide (pyrite), the bronze yellow iron copper-sulphide (chalcopyrite) and the silver-white lead-sulphide (galena). In the absence of native sulphur deposits, the sulphides are important as a source of this valuable substance (see Pyrites).

Except the small quantities of sulphur obtainable as a sublimation product from the crater of Barren Island Volcano in the Bay of Bengal and from the Puga Valley of Ladakh, the sources of natural sulphur in India can be called almost negligible. These sources are too insignificant to meet the demands for sulphur in the country; the demand is met largely by imports.

Sulphur has many important uses, much of the most important being the manufacture of sulphuric acid. With regard to this compound we may quote observations made in 1915 by Sir Thomas Holland, but which remain materially true today.

"Sulphuric acid is a key to most chemial and many metallurgical industries; it is essential for the manufacture of superphosphates, the purification of mineral oil and the production of ammonium sulphate, various acids and a host of minor products; it is a necessary link in the chain of operations involved in the manufacture of alkalis, with which are bound up the industries of making soap, glass, paper, oils, dyes and colouring matter; and, as a by-product, it permits the remunerative smelting of ores which would be impossible otherwise to develop. During the last hundred years the cost of a ton of sulphuric acid in England has been reduced from over £ 30/- to under £ 2/-, and it is in consequence of the attendant revolution in Europe of chemical industries, aided by increased facilities for transport, that in India the manufacture of alum, copperas, blue vitriol and alkalies have been all but exterminated; that the export trade in nitre has been reduced instead of developed, that the copper and several other metals are no longer smelted, that the country is robbed every year of over 90,000 tons of phosphate fertilisers, and that it is compelled to pay over 20 million sterling for products obtained in Europe from minerals identical with those lying idle in India." This state has happily changed and the present capacity of the country for the manufacture of sulphuric acid from native sulphur (imported), about 560,000 tons per year, meets a considerable part of the indigenous demand. Although no extensive deposits of sulphur are known, deposits of pyrite (see p. 151 F_eS_2), which is a raw material for manufacture of sulphuric acid, are widely distributed in the country. Most of our copper-ores occur in the form of copper pyrite which is a sulphide. Such sources of sulphur chiefly occur in Singhbhum district in the copper belt of Bihar State. Pyrite occurs at Amjor in Shahabad district. A reserve of some hundred thousand tons of ore with 40% sulphur is estimated to be available in this area. The sulphides from all these areas may prove suitable for the manufacture of sulphuric acid. Besides Bihar State, pyrites occurs in:

Himachal Pradesh: At Taradevi, to the south of Simla, several lenticular veins of pyrites occur in slates of Boileauganj stage of

the Jutogh series. In one area, the mineralised zone varies from 2 to 5 feet in thickness. The occurrence is over an L-shaped area with an estimated reserve of about 22,600 tons. Pyrite deposits have also been reported near Rampur, Urni and in Bushaher.

Madras: There are several insignificant occurrences of pyrite (iron sulphide) in Salem, Coimbatore and Tirunelveli districts. A fairly large deposit at Thaniar in North Arcot district is being investigated.

Mysore: Pyrite deposits are known in Chitradrug district. Recent diamond drilling by the Geological Department of the State has proved a reserve of 1½ million tons of sulphide ore over a total length of nearly 2,000 feet near Ingaladhal.

Other deposits of pyrite are near Kallehadlu further south of Ingaladhal.

The quality of sulphuric acid required annually in India is about 800,000 tons, which is a very small percentage of the quantity consumed in the U.S.A. in their fertiliser, petroleum-refining, chemical and metallurgical industries. India's requirement is met almost wholly by manufacturing sulphuric acid from imported sulphur. Detailed estimates of the total Indian reserves of pyrite are not available. As a result of the detailed exploratory mining carried out by the Geological Survey of India at Amjor in Bihar, 400 million tons of pyrite of an average grade of over 40% sulphur have been proved. The inferred reserves in this small area are of the order of 700 million tons, a promising amount of deposits.

Due to natural paucity of sulphide ores, derivation of sulphur from this direct source is hardly worthwhile, but it is possible to utilise pyrite, gypsum and other natural sulphates as a source of sulphur.

The present capacity of the country for the manufacture of sulphuric acid is about 600,000 tons per annum, at 48 units.

Vermiculite

Vermiculite is a soft, pliable and inelastic micaceous mineral. It is an alteration product of micas and retains the micaceous clea-

vage. Its colour varies from white to yellow. When heated its volume increases considerably. Due to exfoliation, it expands to 12 or more times its volume on heating. It is used where extreme lightness, *refractoriness*[1] and low heat conductivity are required. Some of its uses are in the manufacture of light-weight concrete for making sound absorbing panels, in making insulators and packing material.

Its occurrences are as follows:

Andhra Pradesh: Vermiculite is reported to occur in Srikakulam district.

Bihar: Important deposits in the State occur about 15 miles east of Ranchi and in a four-mile long discontinuous belt in Hazaribagh district. The reserves of the deposit at Beniajaratola in Hazaribagh are about 4,000 tons. The deposit at Chatra is estimated to contain 3000 tons. Very recently a new deposit of vermiculite has been located by the Geological Survey of India at Kubri in Hazaribagh district.

Madhya Pradesh: Occurrences are reported at Kalikhetar and Pangola in Jhabua district.

Mysore: This State has the largest deposits of vermiculite in India. Deposits are met with in Hassan district, in Tumkur district and in Kolar district.

Rajasthan: Some deposits have been located near Hudas in Ajmer.

Andhra and Rajasthan reported production of 677 tons of *vermiculite* in 1963.

[1] Resistance to fusion.

CHAPTER XVI

RARE EARTH MINERALS

Rare Minerals

The pegmatite veins of the crystalline rocks of India are the carriers of what are called the rare minerals as their accessory constituents. The rare elements contained in them have found use in modern industries such as electronics, high-grade refractories, the manufacture of special steel alloys and other products of highly specialised uses in the present-day industries.

The most common of these are wolfram, beryl, pitchblende and monazite, a compound of some 15 rare earths (which have been already dealt with); columbite and tantalite (niobates and tantalates of the rare earths), torbernite, hatchettolite, brannerite, annerodite, aeschynite, cheralite, allanite and triplite, which occur in the mica-pegmatites of Hazaribagh, Nellore and in Kerala and Rajasthan; samarskite, fergusonite and other allied rare minerals which occur also in these areas; gadolinite (a silicate of the yttrium earths), in a tourmaline pegmatite associated with cassiterite in Palanpur; and molybdenite, in the crystalline rocks of Chhota Nagpur, Godavari Agency, Madura and in the elaeolite-syenite-pegmatite of Rajasthan and Kerala. Thorianite has been found in Kerala containing from 60-80 percent of thoria, uranium (10-30 percent) and helium. Uraniferous allanite occurs in the pegmatites of Nellore with sipylite, a niobate of erbium with other earths. Zircon is found with baddeleyite as residual grains in ilmenite sands in large amounts (over 10 million tons of zircon), less common with uranium minerals and with triplite in the mica mines of Gaya and in the nepheline-syenites of Coimbatore. Cyrtolite is a radioactive variety found in some of these localities. Zirconium is growing in importance as an alloy metal and in atomic reactors. (See strategic minerals).

RARE EARTH ELEMENTS

The name "Rare Earth" was given to the oxides of a group of 15 metallic elements of very similar chemical properties but of restricted occurrence in nature. Some of these in fact are more common than the familiar metals, molybdenum, tungsten, tin, gold or even lead and zinc.

These rare-earth elements are classified into two groups: (1) The cerium group and (2) the yttrium group. Despite similarities in chemical and physical characteristics and properties, minor differences do exist among them. Today they have all been separated in a pure state and their individual characteristics studied.

The cerium group of rare earths is of much wider occurrence in a large number of natural mineral combinations. It is also more intensively studied and is more widely employed in industrial and technological applications than the yttrium group, the utilisation of which in the world's industry and commerce is yet inconsiderable. A note-worthy peculiarity of rare earths is their tendency to occur in groups, or associations of several distinct units in mineral combinations, because of their similarity of chemical properties. Commercial and industrial uses of these minerals are based on this property of group associations, several of rare earths behaving alike. Few single oxides and sulphides of rare earth metals occur as mineral species and no native rare earth metal is known.

OCCURRENCE

The rare-earth minerals do not generally occur as primary constituents of rocks in any concentrated veins or lodes; they are most commonly found in pegmatitic segregations or as subordinate accessory minerals in granite or other igneous and volcanic rocks. Commercial sources of these metals, therefore, are coastal beach-sands or river placer deposits, derived from the disintegration of larger rock-bodies, accumulated in course of geological ages, rather than mines working underground pegmatite veins of bedded deposits. Littoral and alluvial deposits of monazite are of more widespread distribution and form the world's main

resources of rare earth metals which are coming increasingly in demand in industry and technology. Uses of these minerals and metals have been developed at a fast rate in production of glass and ceramics, pyrophoric alloys of the misch metal type, steel and light metal alloys, electronic, photographic and cinematographic applications.

MONAZITE

Monazite is the source of rare earths of the cerium group, of phosphoric acid and of thorium oxide. Of the main ores of Indian occurrence, from which rare-earth metal can be extracted, *viz.*, monazite, allanite, xenotime, samarskite and pyrochlore, the most important commercially is monazite, which is the only one that is put to any commercial use for the extraction of cerium and allied salts and the oxides of thorium and uranium. India's resources in a wide group of rare-earth metals are concentrated in its unique alluvial and placer monazite deposits.

Monazite is a phosphate of the rare earths, cerium, yttrium, lanthanum, didimium, etc. with a variable percentage of thorium and uranium oxide, which it contains as accessory. It is a portmanteau compound carrying some 15 rare-earth minerals. Monazite occurs in the ilmenite sand of the beaches, brought there by rivers draining the hinterland and concentrated by wave action on the littoral. It is found over long stretches of the coast-line on both the Malabar and the Coromandal coasts. On the Kerala beaches wave action has concentrated these heavy-mineral sands into rich placers.

In Andhra State monazite occurrences are associated mainly with magnetite, zircon, garnet and ilmenite. It is found as concentrates in the beach sands of Vishakapatnam. In Mysore State monazite occurs in the vicinity of Bangalore as prismatic crystals, *in situ* in pegmatites, near Yediur; this is, however, not of much economic value. The monazite is derived from pegmatite-veins crossing the charnockites and allied rocks of the high ground; its origin is ascribed to pneumatolytic agencies. Monazite also occurs as a small constituent of the gneissic rocks of the area. The

percentage of thoria in monazite varies from 8 to 10.5; about 0.3% of U_3O_8 is associated with it. In the newly discovered mineral *cheralite* (p. 149) found in some pegmatites in Kerala State, it ranges from 19 to 33%, with 4 to 5% of U_3O_8. The present annual output of monazite is 1500 to 2000 tons, mainly employed in the manufacture of cerium compounds, the thorium being recovered for use as atomic fuel.

Other industrial uses of monazite are in the incandescent properties of thoria, in the oxide of rare earths, and in alloys with magnesium metal.

The total Indian reserves of monazite are estimated at some million tons. Other varieties of monazite from different parts of the east and the west coasts of India show considerable variations in their cerium content from 20 to 31%, yttrium content from 1 to 1.5% and of remaining rare earth oxides from 21 to 30%. An interesting variant of monazite, known as green monazite, and lately described as a new mineral under the name of "cheralite" contains much less proportion of the rare earth oxides and much larger amounts, 29 to 33 percent, of thorium oxide and 4 to 6 percent of uranium oxide. The main habitat of monazite sands are the east and the west coasts of India; deposits of detrital monazite have also been discovered capping the tops of certain plateaus in Bihar State. Besides these secondary, detrital deposits, monazite occurs as a primary mineral also in a number of pegmatites, especially of charnockite and allied granitic rocks, in various inland parts of the country, though they are not yet commercial sources of the mineral. The Indian Atomic Energy Department has undertaken a quantitative survey of the total reserves of monazite on an all-India basis; it is not complete yet, but the provisional estimates place the total reserves of this mineral of great potential value at over five million tons, yielding well over 400,000 tons of combined rare earth oxides.

CHEMICAL COMPOSITION OF KERALA MONAZITE

	Percent
Thoria, ThO_2	8.1
Ceria, Ce_2O_3	30.6
Lanthanum Oxide, La_2O_3 ..	15.7
Prasiodymium oxide, Pr_2O_3 ..	2.9
Neodymium oxide, Nd_2O_3 ..	10.5
Europium, gadolinium and terbium oxides	0.7
Yttrium oxide, Yt_2O_3	0.4
Dysprosium, holmium, erbium, ytterbium and lutecium oxides	0.1
Lime, CaO	1.0
Uranium oxide, U_3O_8	0.3
Phosphoric acid, P_2O_5	26.2

OTHER RARE EARTH MINERALS

Allanite

Allanite (Silicate of cerium, yttrium and iron) containing 2 to 34 percent cerium oxides besides thorium, occurs in pegmatites in the crystalline rocks in various parts of India, at places in bulk aggregates of some cwts., as for example in Nellore and in parts of Orissa and Bihar.

Samarskite

Samarskite is a tantalo-columbate of the rare earths, carrying varying amounts of iron and uranium, cerium group oxides, 2 to 5% and yttrium group oxides, 5 to 21%. Small quantities of samarskite are fairly widespread in the mica-pegmatites occurring in Archaean complex of Rajasthan, Madras and Bihar.

Fergusonite

Fergusonite with a more or less similar composition has been observed along with samarskite in some of these pegmatites.

Xenotime (Yttrium Phosphate)

Xenotime contains 54 to 64% yttrium group oxides. This mineral has not been found in any appreciable quantity in India;

isolated specimens in well-formed crystals have been observed at different places.

Gadolinite

Gadolinite (silicate of yttrium, iron and beryllium) contains 30 to 40% of yttrium group oxides; it is found in tourmaline pegmatites in Rajasthan. These minerals are, however, yet in the nature of museum specimens and are not put to any economic use.

Other Rare Metals of India

The above described cerium and yttrium groups of metals, conventionally called rare, by no means exhaust the list of what may more appropriately be designated as the rare metals of India. Amongst these are to be included the atomic metals—uranium, throium, beryllium, lithium and zirconium; the less common metals of strategic value in the alloy industry such as molybdenum, titanium, tantalum, columbium, tungsten, vanadium; and metals used in some highly specialised industries—gallium, germanium, hafnium and tellurium. Any sketch of India's resources in rare metals would not be complete without the inclusion of these metals. Since those groupable as "atomic metals" find mention in a separate place in Chapter XVII, those groupable as "Alloy Rare Metals" are described below:

ALLOY RARE METALS

Molybdenum

Molybdenite (MoS_2—Mo 60%) is the principal mineral. It occurs in the Khasi hills, Hazaribagh district of Bihar, Godavari district of Andhra Pradesh and Madura district of Madras State.

Titanium

The major source of this metal is ilmenite ($FeTiO_3$) beach sands, "Black Sands" of the Malabar and Coromondal Coasts, with 55 to 62% TiO_2. It occurs as alluvial deposits and as vein deposits in Bihar. The former is the most important source of the metal titanium. Estimated reserves are of a high order,

calculated at over 150 million tons. Rutile (Ti-60%) occurs in association with ilmenite sands in alluvial and placer deposits. (See Chapter XII).

Columbium and Tantalum

The two minerals columbite and tantalite grade into each other (at places in association with samarskite) by isomorphous replacement. The combined Nb- and Ta-oxides in them are generally high, ranging over 40-70 percent. Columbite generally occurs in rocks of the Dharwar System, as a jet-black mineral associated with sporadic pockets in pegmatites. A few tons of this mineral were exported in the past, but the supply is mostly fortuitous. Increasing demand should call for systematic exploration. Tantalum, which is exceedingly rare in the native state in nature, is a hard, heavy, white and ductile metal of great tensile strength. Tantalum was formerly used in the manufacture of filaments in electric bulbs. Its modern use is in the production of special steels, particularly those used in making dental and surgical instruments. Ferrotantalum alloys, which are made from tantalite, are used as electrodes in electric furnaces and in the manufacture of hard tantalum carbide which is used in steel making.

Columbite-tantalite most frequently occurs in association with beryl in pegmatites traversing mica-belts (especially in their more barren parts) in Bihar (Gaya area), Rajasthan, Madras (Nellore area), Mysore and Kerala States. Occurrences are also known in Tiruchirapalli district and in the mica mines of Salem and Coimbatore districts.

Tungsten

The chief ore of this valuable strategic metal is wolfram (WO_3-70 to 75%). The mineral occurs very sparingly in Jodhpur and Nagaur districts in thin veins and stringers and in a few alluvial deposits. Production has been small and fitful; barely a few hundred tons have so far been obtained from these localities.

Vanadium

This metal occurs in vanadiferous titanium-iron ores in igneous rocks in Dalbhum and Mayurbhanj districts of Bihar; V_2O_5 content is small, generally not exceeding 0.8 to 3%, but the total volume of vanadiferous ore-bodies found in this district is fairly extensive. Vanadium in traces is also observed in the ashes of some coals and lignites of both Tertiary and Gondwana ages.

The remaining rare metals occurring in India are less important.

Hafnium

This has been found as a fairly constant constituent of Zircon along with the zirconium (HfO_2-3.2%). The metal is an absorbent of neutrons, like cadmium.

Rubidium

It has been found with lithium in lepidolite in insignificant quantities.

Gallium and Germanium

They are among the scarcest metals so far separated. Gallium has been observed in minute traces in some parts of India in ores of aluminium near Ranchi, some of the manganese-ores from Nagpur and gold-ore in Andhra regions. Germanium has been observed in traces in ashes of some coals from Assam and Singareni and in Sphalerite (zinc-ore) of Zawar and Nepal.

Tellurium

It occurs as telluride in combination with gold ores in Kolar and with copper ores in Singhbhum and Assam.

The occurrences of the above-named rare metals are, for the present, of only scientific interest in the country and there has so far been no commercial production of any of the metals mentioned above.

The Precious Metals

To sum up, the position set down in previous chapters, gold, platinum, iridium, osmium, etc., with the exception of gold (the production of which has in the last few decades fluctuated from 6,00,000 fine ozs. to the current 2,00,000 fine ozs. per annum, mostly from the Kolar mines, Mysore,) none of the metals of this group occur in any appreciable quantity in India. Platinum, iridium, osmium have been observed in traces in the alluvial gold washing in Chhota Nagpur, Singhbhum and in the bauxite residues of Madhya Pradesh and Maharashtra.

CHAPTER XVII

MINERALS AND NATIONAL RECONSTRUCTION

1. Review of Present Mineral Position in India

Deposits of useful minerals and rocks have been worked in India for many centuries, though, generally in a small way. In the medieval ages India had a fairly developed metallurgical industry, that used to produce its own metals, both ferrous and non-ferrous, and satisfy most of its indigenous needs. The immense quantities of slags of iron and steel and metals like copper, zinc, lead and gold, and, to a smaller extent, silver and cobalt, in parts of Rajasthan and Bihar and several centres in the Deccan, bear testimony to the existence of a flourishing and vigorous metal industry in the past. In certain of these districts, slag dumps cover miles of the countryside and, in one instance, the crucibles used for smelting zinc and lead are spread over a hill-side on which a whole village is built. This fact indicates that profitable mining operations must have been carried out for many centuries in various parts of the country. The famous iron pillars forged of remarkably pure rustless iron, manufactured in the early centuries of Christian era (one such, that of Delhi, is 23 feet long), and the celebrated *wootz*, the steel used for Damascus swords, are well-known examples of the art of ancient Indian metallurgy. Of course, the ancients were content to exploit only the small, easily accessible deposits without any particular reference to their grade or richness. Minerals like coal, oil, chrome-ore, manganese, mica, ilmenite, etc. were altogether untouched till almost the end of the eighteenth century, when the impressive development of the western world brought these minerals to the notice of European capitalists, who started large-scale operations for mining these minerals for the purpose of foreign export. In most cases the existence of old workings guided these explorations and development. The 24 more important products mined annually in India today are:

1.	Coal	..	66,000,000 tons
2.	Iron-Ore	..	15,000,000 "
3.	Manganese-Ore	..	1,200,000 "
4.	Mica	..	20,000 "
5.	Salt	..	10,500,000 "
6.	Building materials	..	Value, Rs. 15 crores
7.	Gold	..	5,000 Kg.
8.	Petroleum & Natural Gas		4,000,000 tons
9.	Copper-Ore	..	475,000 "
10.	Ilmenite	..	200,000 "
11.	Industrial clays	..	750,000 "
12.	Glass Sand	..	220,000 "
13.	Lead and Zinc-Ores	..	16,000 "
14.	Chromite	..	70,000 "
15.	Kyanite and Sillimanite		60,000 "
16.	Magnesite	..	230,000 "
17.	Steatite	..	100,000 "
18.	Gypsum	..	1,050,000 "
19.	Monazite	..	2,000 "
20.	Beryl	..	800 "
21.	Limestone & Dolomite		23,000,000 "
22.	Fuller's earth	..	36,000 "
23.	Rutile	..	2,000 "
24.	Bauxite	..	625,000 "

Less important mineral products today but which are capable of material development in future expansion of industries, with application of technical knowledge, skill and enterprise are :

25.	Agates	Production variable and generally small.
26.	Antimony	"
27.	Apatite	"
28.	Asbestos	"
29.	Barytes	"
30.	Borax	"
31.	Corundum	"
32.	Felspars	"

33.	Graphite	Production variable and generally small
34.	Mineral waters	"
35.	Ochres	"
36.	Silver	"
37.	Tungsten-ore	"
38.	Zircon	"

The above table shows in conspectus the mineral output position as it is in India today. The annual production in terms of Rupees is valued at a little over 250 crores. This figure is, however, rather low, as in many cases, only the pit-head value of the mineral is calculated.

2. Past Neglect of Systematic Mineral Exploration in India

Until very recent times exploration of ores and minerals for industrial utilisation on a consistent rational plan had received no attention. The bulk of mining was done with European capital and technical skill, but for the solitary exception of a Tata, whose vision and enterprise brought into existence Jamshedpur and an iron and steel industry on a scale somewhat commensurate with its vast reserves. This fact remained true upto World War II. As a result of this an unhealthy and uncontrolled traffic in India's minerals grew up. Excepting coal, oil and iron-ore, required for internal consumption for basic needs, the bulk of minerals was raised only for purposes of export entirely in the crude condition without any processing, dressing, curing or fabrication, *e.g.*, the whole output of manganese-ore, mica, ilmenite, chromite, refractories and the major part of the remaining six or seven minerals raised in India. These exports brought but a small return to the country either in the shape of adequate prices or exchange commodities in which India has been deficient.

India's coal resources have been a subject of long examination and considerable debate. Although over 75,000 million tons are known to be present in Indian rocks, the extractable quantity within 2,000 feet depth from the surface have been variously estimated between 30,000 million and 40,000 million tons. The reserves of superior-grade coking and metallurgical

coal, however, are believed to be not more than 2,000 million tons. This superior-grade coal, however, has in the past been indiscriminately drawn upon for railway and factory uses, a fact which gave rise to serious misgivings about the future of metallurgical industries in India, especially iron and steel, the ore reserves for which are of a vast magnitude. Till lately Indian coal was the cheapest in the world and its very cheapness at the pitheads led to the wasteful employment of the better grades and to the adoption of cheap, crude methods of mining. In raising the annual quota of 25 to 27 million tons of coal for India's local consumption in the pre-war years, it has been estimated that at least an equal quantity has been lost, or rendered useless underground through fires, roof collapses, subsidences and unscientific mining methods. Luckily energetic steps are taken now to control these wasteful practices. In the absence of organised scientific research, Indian mineral industry kept on stagnating upto the beginning of World War II. Till then the Geological Survey of India directed its energies chiefly to academic problem and geological mapping, because of limited personnel on its staff. Systematic mineral exploration was confined to manganese and aluminium-ore (bauxite) and occasional spasmodic drilling campaigns to prove suspected coal or ore bearing areas. Since 1944, however, this gloomy picture has been changing. The creation of a Department of Planning and Development in the Central Government, the establishment of the Board of Scientific and Industrial Research, a programme of four-fold expansion of the Geological Survey, the formation of a national mineral policy and the Bureau of Mines as its mouthpiece, promised a new era for mining and mineral industries on modern and progressive lines. These promises are being fulfilled by means of realignment of the Geological Survey of India with major emphasis on mineral exploration and development, the coordinated mining and conservation of the country's mineral assets and the Mineral Policy of the Government over the last two decades; the position has materially changed for the better.

3. THE CHIEF MINERAL ASSETS OF INDIA

(i) The following products and Indian mines may be classed as of world importance:

Iron-ore and manganese-ore,
Ores of aluminium, magnesium, titanium,
High-grade refractories,
Rare earths and metals,
Mica,
Thorium and other atomic elements of strategic importance.

These provide workable basis for well-regionalised mineral, metallurgical and heavy engineering industries. Reserves of iron-ore (current estimates put them at 20,000 million tons), manganese, aluminium and magnesium-ores are such as to make India the leading metal-manufacturing country in the East in the near future. Iron and steel production can be increased to many times its present output of barely 4 million tons. Abundant local resources exist for large-scale manufacture of ferromanganese as well as silicon-, chrome-, vanadium-, titanium- and other steels, with a wide range of light-metal alloys. The outstanding problem that confronts the metal manufacturer in India is, however, not so much the paucity of ore reserves as ready access to coal supplies, which are confined to a narrow sector in East India. Low-cost electrical power, or, in due course, Atomic power is thus the decisive factor in the regionalisation of heavy and light metal industry in parts of India remote from the eastern India coalfields.

(ii) *Ferro-manganese and Ferro-alloys:* Being the world's largest supplier of high-grade manganese-ores with an annual output approaching a million tons, it should be possible in India to manufacture 200-300 thousand tons of ferro-manganese per year and export that commodity rather than raw manganese-ores. Low-phosphorus ores and low-phosphorus coke are available for this purpose at a few localities.

(iii) *Light Metals and Alloys:* Large reserves of light metals aluminium and magnesium, which are yet scarcely touched, exist in suitable concentrations in South India. Good-grade beryllium-ore occurs in fair amount and a prolific source of titanium, "the

metal of the future", exists in ilmenite. Prospects for the manufacture of light-metal alloys, which are now in increasing demand for a surprisingly wide range of engineering requirements, are particularly bright and should have foremost place in a programme of reconstruction. These metals can largely replace our deficiency in copper, zinc and lead. Electro-metallurgy, the chief mode of production of these metals, uptil now has not made much headway, but with the installation of hydel plants in connection with the five great River Projects, one big gap in the cheap supply of thermal energy will disappear. A stable metal industry demands, besides fuels, easy access to fluxes, refractories and subsidiary minerals. Reserves of most of these are ample and well distributed.

Mica: This forms another important mineral asset. It is the only Indian mineral the exports of which had brought a fair monetary return; because India has demanded and obtained almost monopolistic prices in the world market. Almost the whole output is exported which supplies 80% of the world's demand of superior-grade mica. In preparing this quantity of mica by cutting and grading to standard specifications of foreign buyers, an enormous amount of waste mica is produced. A profitable outlet for the utilization of the vast dumps of this waste product at a number of localities may be found in the making of paints, boards, moulded insulators, micanite, extraction of potash, etc.

Water and Soils: In an assessment of the mineral wealth of Indian outlined above and in the foregoing chapters, must be included the reservoirs of underground water, the mighty rivers flowing from the snows of the Himalayas and the soils covering the vast alluvial plains. These form natural assets of the highest value in the country and are, in various ways, ancillary to its mineral development. The 300,000 sq. miles of fertile soil of the Great Plain of Indus-Ganga possess agricultural and underground water resources, the full potential of which needs to be realised.

4. Mineral Deficits in India

(i) *Non-ferrous Metals*: In contrast with the sufficiency of ferrous metals dealt with in the preceding chapter, the position

in India with respect to tin, lead, zinc, nickel, silver and mercury and, to a lesser extent, copper is distinctly unfavourable. An extended and detailed geological prospecting of the mining areas which are known to have supplied the by no means insignificant demand for copper, zinc and lead in the years before the 19th century, however, is necessary before we can finally accept these deficits. Medieval India supported copper, zinc and lead-mining and smelting industries in Rajasthan, Bihar and in some centres in Deccan. The Darjeeling—Gangtok and other Himalayan copper-ores need more extensive exploration and drilling tests; as has been the case in the Khetri copper and the Zawar lead-zinc deposits of Rajasthan. At these centres geophysical prospecting and deep drilling tests may prove some deposits that may be worth working on a modern scale.

(ii) *Petroleum*: India's hitherto known oil deposits give ground for a rough forecast of possible reserves. Oil-bearing rocks of India are confined to the strip of Tertiary rocks bordering the extra-Peninsula. This strip joins up the Iranian oil arc with the Burma-Java arc, two prolific oil belts of the old world. The energetic prospecting of this Tertiary belt in late years has yielded encouraging results. Three potentially pertroliferous regions which can be regarded as promising for intensive prospecting by modern methods are:

(1) southern Assam hidden under the Brahmaputra alluvium;
(2) the shallow submarine tract of the Cambay Gulf, Gulf of Kutch and southern Rajasthan buried under the desert sand;
(3) certain areas in the Outer Himalaya and its piedmont tract.

Against a consumption of over 10 million tons yearly, the present annual production of petroleum in India has reached a figure of 4 million tons, produced by the Assam and Gujarat oilfields. Future progress of oil development in India can only be looked for from the application of the new highly perfected technique of depth exploration by seismic and gravimetric methods, in zones

with promising geological structures; Coastal and deltaic tracts and off-shore drilling offer reasonable prospects of success.

(iii) *Non-metallic Minerals* like sulphur, graphite, potash, cryolite. For these, India depends wholly or largely on imports.

5. India's Position in The World's Mineral Map

An overall picture of India's mineral resources, via-a-vis the world, its surpluses, sufficiencies and deficit, is presented in the following table which gives a bird's eye view of India's position on the world's mineral map:

(*a*) Minerals of India which are of world importance:

Iron-ore	Titanium-ore
Mica	Thorium-ore
Rare metals and earths	

(*b*) Minerals in exportable surpluses and which are available for exports on reciprocal basis:

Bauxite	Monumental granite
Corundum	Natural abrasives
Magnesite	Sillimanite and Kyanite
Manganese-ore	Silica
	Steatite

(*c*) Minerals in which India may be considered self-sufficient for present need and for those of the immediate future:

Alum	Glass-sand
Aluminium	Gold
Antimony	Industrial clays
Arsenic	Limestone, dolomite
Barytes	Marbles
Building stones	Mineral pigments
Cement raw materials	Precious and semi-precious stones
Chrome ore	Sodium salts and alkalies
Coal	Uranium
Feldspars	Vanadium
Fluorides	Zircon

(*d*) Minerals which are absent or in short supply in India and for which she has to depend on imports:

Asphalt	Platinum
Bismuth	Potash
Cadmium	Silver
Graphite	Sulphur
Lead	Tin
Mercury	Tungsten
Nickel and cobalt	Zinc
Phosphates	

6. Strategic Minerals of India

During World Wars I and II, the exhaustion of minerals and metals used up in munitions and destructive operations on land and sea and in air had been so great that several minerals and metals have reached almost exhaustion point. These wars have caused depletion in resources in tin, nickel, cobalt, lead and zinc in the world. The nickel, lead, zinc and tin supplies are calculated to last only a few decades, if they are drawn upon at the present rate from hitherto known sources. In a world with its depleting mineral assets, India's strategic minerals position demands examination.

"Strategic" minerals include, besides material for war munitions, all mineral raw materials, which are required for industrial sufficiency and preparedness for defence. Domestic resources in many of these minerals are ample and well distributed. In respect of strategic minerals, India is well supplied and in some of them she has considerable exportable surpluses. The position, however, is nebulous in the case of "critical minerals" (*i.e.*, minerals of essential uses, the supply and procurement of which in adequate amount in the event of any national emergency is uncertain). There are serious gaps and deficiencies in these minerals. In peace-time economy this distinction, perhaps, does not have much significance; but in the event of active national crisis, lack of sufficient reserves of certain mineral raw materials, even though relatively unimportant in themselves, may imply grave hazards to

the country's security. This would be so even in the face of abundance of other "strategic" minerals. Among such "critical" minerals in short supply in India, the more important are: some petroleum products, sulphur, base metals, *e.g.*, lead, zinc, copper, cadmium, nickel, tin, mercury and platinum, and minerals, *e.g.*, industrial diamonds, graphite, alkalies, potash, selenium, *etc.*

India's resources in strategic minerals of world importance are: abundant and rich iron-ores, ores of manganese, titanium, thorium and of the light alloy metals, aluminium and magnesium. There is a sufficiency of ores of ferro-alloy metals, chromium, vanadium, tungsten and flux minerals, refractories, abrasives, bauxite, industrial clays, while in its resources of mica, manganese, ilmenite, monazite and beryl, essential for a wide variety of strategic uses, India occupies a commanding, if not a controlling position.

As shown in the table below, of the 26 minerals and metals considered vital for national defence, India is lacking in ten:

Abundant or sufficient	Deficit
Aluminium	Graphite
Antimony	Lead
Coal	Mercury
Chromium	Nickel
Columbium	Platinum
Copper	Potash
Iron	Sulphur
Magnesium	Tin
Manganese	Tungsten
Molybdenum	Zinc
Mica	
Tantalum	
Titanium	
Thorium	
Uranium	
Vanadium	

Atomic Metals

The most important of these are uranium and thorium.

URANIUM

Uranium occurs as disseminations and impregnations in Archaean crystalline schists and pre-Cambrian metamorphosed slates and phyllites in Bihar and some parts of Himalayas. It also occurs in pegmatites; but a more reliable and substantial source of uranium lies in the deposits of monazite sands—both beach and alluvial (see Chapter XIV).

Compounds of this highly strategic metal of increasing value as atomic fuel in Nuclear Power Reactors are found in India associated principally with crystalline, igneous and metamorphic rocks. Here uranium mineralisation is associated with sulphidic copper and oxidised iron, rather than with gold, lead, zinc or vanadium ores. No appreciable quantity of uranium has been found in sedimentary rocks, though its occurrence in phosphatic, bituminous and lignite deposits at several places has been noted. The uranium-ores of India belong to three categories:

(1) Pegmatitic: Pitchblende and complex niobates, tantalates and titanates of uranium, *e.g.*, samarskite, fergusonite, brannerite, etc.

(2) Uranium compounds impregnating rocks that have been involved in orogenic movements giving rise to larger shear and thrust-planes, *e.g.*, along the Singhbhum Copper Belt in Bihar and the tightly compressed rocks of the Aravalli synclinorium in Rajasthan. Here the uranium compounds occur in thin disseminations yielding from ½ lb to 2 lbs of uranium to the ton of rock, the uranium content varying from 0.03 to 0.1% is commercially extractable.

(3) Monazite, occurring in large beach-sand deposits on the east and the west coasts of India and in some places in Bihar, carries a small fraction from 0.2 to 0.4% of uranium oxide. The rare mineral cheralite, a variant of monazite, contains 4 to 6% U_3O_8. Over 15,000 tons of uranium is estimated as probable reserve contained in monazite.

Pitchblende (uraninite) occurs in nodular aggregates and patches of basic segregations in pegmatite veins in the Singar Mica Mines of Gaya (Bihar) and in the mica pegmatites of Nellore and

at Ajmer. Autunite, torbernite, carnotite, columbite, samarskite, triplite and allanite are usual associates. In the mica pegmatites of Sankara mines of Nellore, masses of samarskite, weighing upto 200 lbs. have been met with, while pitchblende in nodules upto 36 lbs. was found in the Gaya pegmatites. The main uranium reserves of the country, however, are not in the pegmatites, but they lie in the deposits mentioned in categories (2) and (3) above.

Reserves of uranium in India, according to investigations carried out by the Department of Atomic Energy, Govt. of India, are calculated at 30,000 tons. Further geological, geophysical, aerial surveys with airborne radiometric instruments are likely to reveal more than double this amount of commercially workable uranium ores from lesser grade deposits.

Thorium

The main source of this rare heavy metal, a likely future substitute for uranium in atomic energy reactors, is monazite, which contains upto 10% of thoria and 0.3% of urania; other minerals carrying thorium is thorianite (ThO_2—70% with uranothorianite). The resources of India in thorium, the "fertile" fission metal and the potential atomic fuel of the near future, are of considerable magnitude. The known Indian reserves of thorium oxide are estimated to be between 4,50,000—5,00,000 tons.

The very rare mineral thorianite (ThO_2—70%), which is found in the crystalline rocks of Ceylon in commercial quantity, is found as a rare constituent of some Kerala ilmenite sands.

Beryllium.

Besides its use in a number of valuable metallurgical alloys mentioned under "Beryl" elsewhere, beryllium oxide is of use as a "moderator" in Nuclear Reactors for Atomic power generation. The reserves of beryl in India being considerable, it will be able to meet all indigenous demands for atomic as well as metallurgical uses.

Lithium

This light metal has sprung into strategic prominence in experiments on the production of atomic energy through thermonuclear fusion of light elements. It is found in the minerals lepidolite 2.5 to 5% Li_2O, and spodumene (5 to 8% Li_2O). The former mineral is fairly widespread in the mica belt of Bihar, Madhya Pradesh and Rajasthan, the reserves of which are ample for future requirements.

A deposit of lithium-mica, lepidolite, has been found in the Bastar region of Madhya Pradesh—Orissa in the form of boulders of lepidolite aggregating a few hundred tons. It is capable of supporting a small industry for the manufacture of lithium salts rather than for the extraction of lithium metal.

Zirconium

India possesses large resources of this rare metal in the mineral zircon (ZrO_2—65%) which forms about 6% of the well-known ilmenite beach sands of the Indian coasts, particularly the Kerala coast. Zircon sand contains baddeleyite, another zirconium mineral. Zircon concentrates also occur in the alluvial soil in Ranchi and Hazaribagh districts of Bihar. Not occurring free in nature, this greyish metal is extracted from the mineral zircon, which is silicate of zirconium. Zirconium is alloyed with iron, silicon, tungsten, etc. It is also used for removing oxides and nitrides from steel and in making flash lamps of various kinds. Zirconia, the oxide of zirconium, is used as a refractory in abrasives, in enamels, etc. Pure zirconium possesses some valuable properties: resistance to heat and corrosion and complete inability to capture thermal neutrons. It has, therefore, lately attained prominence as a structural and cladding material in Atomic reactors. Cyrtolite is a radioactive variety, containing a small percentage of U_3O_8. An exportable surplus of zircon exists in India. (For "Zircon as a gem stone", see under "Previous Stones".)

Titanium

Ilmenite is the chief ore. Reserves of ilmenite (TiO_2—50-

60%) are computed at nearly 150 million tons. Though these reserves are large, they are by no means inexhaustible at the rate of depletion that was prevalent in the years previous to World War II. Kerala State has started manufacture of titanium-paints locally on a small scale. Titanium, "the metal of the future", possesses some extraordinary properties for use in industry and commerce as well as for defence purposes (see under "Titanium".)

The "critical minerals" being in short supply, the country's position in respect of "strategic minerals" presents a state of disequilibrium. This may not matter in times of international peace, but is a double risk to national security in situations of international disturbance, when imports of essential commodities may be jeopardised and the off-take of credit earning exports may be reduced if not stopped altogether. A healthy economy can be achieved by balancing, as near as possible, the surpluses against deficits through building up civilian industrial power for production of substitutes for some deficient and submarginal commodities and stock-piling of others.

CHAPTER XVIII

NATIONAL MINERAL POLICY AND PLANNING OF MINERAL DEVELOPMENT

Bearing in mind the very late beginning of a national mineral policy in India (stated in the preceding Chapters), the plans for the future have to provide for detailed and intensive exploration of the country's mineral resources as well as their conservation and utilisation for indigenous manufacture and fabrication. Geophysical exploration for oil, first carried out by Oil Companies for some time and only recently started on a systematic scale for other minerals like base metals, promises attractive dividends from certain Indian terraines. The fact is now recognised that the 2000 miles long border of the great alluvial plains overlapping the crystalline rocks all round it and other large areas buried under deltas, deserts and ancient lava-flows need systematic geophysical sounding. It is a reasonable speculation that some of these formations mask extensions of: (1) ore-bearing rocks in Dharwar, Rajasthan, Karnatak; (2) coal-bearing rocks in the Upper Godavari Mahanadi valleys; (3) oil-bearing older Tertiary rocks in Punjab, Rajasthan and Assam. These blanketed areas of India which aggregate over half a million sq. miles are beyond the reach of ordinary geological prospecting. Gravimetric, magnetic and seismic reflection and refraction surveys are likely to locate deep-lying ore-masses, oil-pools in off-shore areas, coal-fields, water-reservoirs and some hitherto unsuspected mineral occurrences. A nation's progress and power potential are largely measured in terms of its mineral wealth and its ability systematically to explore, process and use it to the best advantage. There are roughly about 2,000 species of known minerals in the world and of these barely 200 are of direct use in man's pursuits. The advancing technology of the last decades has brought into use an increasing number which finds application in commerce, industry and arts of today. These economic minerals are classified into 'strategic minerals,'

critical minerals, key minerals and the remaining common minerals, although the distinction is not rigid and is fast disappearing. For practical purposes every country looks at its mineral resources from the viewpoint of its surpluses, sufficiences and deficiencies. To-day every great world power assesses its mineral potential from the viewpoint of military strategy and internal defence; stock-piles of deficit strategic minerals are built up against possible eventuality of aggression.

There is a mounting list of minerals and metals, which are brought into use in the manufacture of weapons of national defence; these are the rapidly growing pile of new atomic weapons, jet-propelled engines, rocket-planes, space-explorers and their highly specialised electronic accessories. An immense range of new metallurgical products, ferrous, non-ferrous and light-metal alloys, fluxes and refractories are included in this category. The most important minerals in present-day planning are, therefore, the essential and basic minerals and metals which are on the industrial and defence programme of a nation. These are stock-piled and earmarked for defence emergency and are regarded as minerals of prime importance. The second category include besides primary raw-meterials, non-metallic minerals like mica, kyanite, graphite, etc. and ores of rare-metals, *e.g.*, germanium, zirconium, cerium, caesium, etc., which feed the modern specialised industries. The third group comprises all the metallic and non-metallic natural products which supply the needs of daily life and international commerce and communications.

From the world's mineral map we see that while India has reserves of great importance in iron, manganese, aluminium, titanium, thorium and mica, the number of deficiencies (outlined in an earlier chapter) is also considerable, in some respects even serious, *e.g.*, in some petroleum products, tungsten, mercury, tin, lead, nickel and potash. While in the former group India occupies a commanding, if not a controlling, position, in the latter her position is one of dependence on foreign imports, though in some cases (*e.g.*, petroleum, copper and sulphur) the situation has somewhat eased recently. There is an intermediate group of

minerals in which India is self-sufficient for the present and the immediate future, *viz.*, in her resources of atomic metals, ferro-alloy metals, fluxes, rare earths, refractories, bauxite and industrial clays. Bearing in mind this disequilibrium, a balanced development has to be planned on a nation-wide basis for peace and of international disturbance. A healthy dependence on our mineral resources has, therefore, to be planned on a pattern similar to that of the U.S.A. in post-War years: (1) balancing, as far as possible, surpluses against deficits by a system of exchange or barter with the industrially more advanced countries; (2) building up a strong, civilian, peace-time industrial power; (3) production of synthetics and substitutes for deficient and sub-martinal commodities; and (4) stock-piling of some 10 essential deficit minerals and raw products for emergency use.

It is by the adoption of such means as these that countries unendowed by nature with minerals have yet built up a high industrial potential. Germany and Japan may be cited as prominent examples of such deficit countries who have reared a great industrial structure strong enough to stand two World Wars, without themselves having most of the essential mineral resources. Their long-range, well-calculated planning and the long lead they had in pre-War years in carrying stockpiles of important raw material saw them through those years of emergency.

To the extent that India has remained comparatively undeveloped in the 20th Century world's industrial race, as well as uninvolved in the Wars of the last century, her mineral stock has not been drawn upon to a wasteful extent. Under the circumstances, a planned programme of future mineral development has primarily to take into account the natural assets and deficits mentioned in the previous Chapter. Hence national economy demands that India's mineral production and its conversion into industrial manufactures within the country should bear proportion to the volume of her main natural reserves.

Such programme of mineral development basically calls for:

(1) Intensive and systematic geophysical investigation.

(2) Maximum utilization of the resources in iron, aluminium,

magnesium, titanium, thorium, beryllium, vanadium;

(3) Domestic treatment and processing of raw minerals instead of their export in the raw condition;

(4) Development of important, low-cost sources of power and energy (for regions not supplied by coal) from Hydel plants, Atomic Reactors, Solar energy, Tidal power, etc.

Planned Programme of Mineral Development

A planned programme of mineral development somewhat on the above lines and in conformity with modern trends of world mineral economics may radically alter India's mineral position. The list of minerals given elsewhere may undergo a complete change both as regards the minerals named and the financial returns shown against them. For instance, the production of aluminium from bauxite; aluminium-, magnesium-, titanium-, beryllium-alloys (if carried out on a scale commensurate with the magnitude of these resources), production of ferro-manganese; titanium-paints; processing of high-grade refractories; manufacture of industrial products from the rare-earth minerals are the big possibilities for the future. The annual statistics of gains from such a production programme then may come to bear no relation at all to the present meagre returns from these minerals.

The Future

Man's progress in civilization from the barbaric stage has been punctuated by his mastery over minerals and metals. Ever since his emergence from the Neolithic Age, pursuit for metals and the development of metallurgy have been the key-stones of his economic welfare and industrial progress. Tools made directly or indirectly out of metals and minerals, defence armaments and munitions (now supplemented by atomic weapons) all depend largely on the product of mines. Minerals thus form one of the modern world's important resources in the support and fulfilment of human life. It is this very civilisation that has caused enormous depredations on the stock of minerals in the accessible

parts of the earth. The very wide range of their uses has made great inroads on the world's stock of minerals, in some cases to such an extent that their accessible stocks in the earth's crust are reaching depletion point. The question arises whether in the coming centuries, the reduced minerals supply position will affect, and to what degree, man's industry and well-being. In this depletion of the earth's stock of minerals, wars have played the biggest and the most sinister part; because, the wars of the present century have used up, or destroyed, or put out of action more basic metals and minerals than were consumed during the whole course of human history. The diminishing reserves of such minerals, as lead, tin, zinc, copper, nickel and eventually of petroleum and coal, have called forth warning notes from geologists and industrial economists. But it is evident that in spite of these the tempo of consumption of minerals is steadily rising and will increase to such an extent before the 20th century closes, that mankind will be confronted with problems of replacement of some exhausted minerals by non-mineral products, such as plastics, glass, ceramics, etc. The impending scarcity can be put off for a few generations to come by such measures as substitution of plastics and light metal alloys which are in more abundant supply, together with new discoveries of mineral reserves in hitherto unexplored territories of the world and resort to such means as deeper mining and refining of substandard raw minerals and ores. But the lesson of mineral depletion from the accessible parts of the earth's crust should be taken as nature's grim warning that modern man is spending away a prime potential of earth which is non-replenishable. How this will affect the trends of world progress and our notions, of civilization eventually, or in what manner human ingenuity, science and technology will answer the situation seems unpredictable at present. But, India sooner or later, depending on its surpluses, sufficiencies, deficiencies and the planning of it all will have to share the world trends.

Till such an eventuality arises, the intervening years will bring into prominence in India, as in the rest of the world, atomic minerals uranium, thorium, lithium and a number of subordinate

mineral substances required as fuel or as moderator or reflector in nuclear reactors, or in fabricating of structural or shielding parts of atomic reactors. Harnessing of this new energy source, atomic energy, for industrial power within near future to replace the dwindling coal and oil fuel resources, requires no prophetic vision. This developing phase of human endeavour is bound to be integrated with future civilisation. The world's resources of uranium are not scanty, and, supplemented by thorium in the near future, further accelerated by the current strides in nuclear physics research, will facilitate more and more the employment of nuclear fuels in preference to fossil fuels. This will relieve the pressure on the depleting world reserves of coal, petroleum and natural gas which, according to geological belief, will not at the present rate of consumption, last for more than 8 to 10 decades even in parts of the world best endowed with these, *e.g.*, the Middle East, U.S.S.R., Sahara, China and the U.S.A.

However planned a programme of mineral development may be, a time will be reached when there will be no minerals left in the humanly accessible parts of the earth. The duration of the "Mineral Age" itself in human civilisation will depend on the rate at which it reaches the exhaustion point of the mineral resources. Distant future will recognise the "mineral culture" of the present age as a passing phase of human civilisation and the science of mining as an ancient science. Its literature and technique will be looked upon by posterity as a phase in the sum total of man's knowledge in a bygone age. The "Metal Epoch" (for that is what it might come to be known as) of human civilisation will arouse the academic curiosity of only students of human history much as the present day archaeologist, the anthropologist and the historian is interested in the "Stone Age" and later ages gone by. It is sad to imagine that if the substitutes for the vanished minerals and metals prove more handy and effective the very science of present-day mineralogy and the mining techniques would be patronisingly described as laborious processes of a half-civilised age in building up human welfare—a welfare which they themselves destroyed by depleting the minerals through over-production. If, however, on

the other hand, the world of the future is destined to be handicapped by the absence of minerals and if it finds their substitutes hard to win and not serviceable enough when won, according to contemporary standards, the age of minerals will be immortalised as the golden age of human civilization with utmost reverence to the savants who knew the great science and with a degree of admiration which might well outstrip our present reverence for the metallurgical knowledge of the ancients who created long-lasting monuments of the world, such as the Iron Pillar of Delhi and the pyramids of Egypt.

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